

CHEMISTRY

Paper 9701/11
Multiple Choice

Question Number	Key
1	B
2	B
3	A
4	D
5	D
6	C
7	A
8	A
9	D
10	C

Question Number	Key
11	B
12	C
13	D
14	B
15	B
16	C
17	A
18	C
19	A
20	C

Question Number	Key
21	B
22	D
23	D
24	D
25	C
26	C
27	A
28	C
29	B
30	A

Question Number	Key
31	C
32	C
33	A
34	D
35	B
36	D
37	B
38	B
39	D
40	A

General comments

This examination paper provided a difficult challenge to the candidates. Most candidates were able to complete the paper within the hour allowed.

Candidates found comparatively few questions easy. **Questions 1, 6, 12, 25 and 40** were found to be the easiest.

Many candidates found **Questions 3, 5, 7, 10, 30 and 39** to be particularly challenging.

Comments on specific questions

Question 3

Each of the other three incorrect options were chosen by an approximately equal percentage of candidates. It can be calculated that 5.0g of calcium is 0.12 moles which produces 0.12 moles of hydrogen when reacted with water. 5.0g of potassium is 0.13 moles which produces 0.06 moles of hydrogen when reacted with water. Similar calculations show that 5.0g of rubidium and 5.0g of strontium also produce less hydrogen than 5.0g of calcium, so the correct answer is calcium.

Question 5

The most common incorrect answer was **B**. The shape of sulfur hexafluoride is octahedral, an octahedral structure has both 90° bond angles and 180° bond angles. The 180° bond angles are F-S-F bond angles which arise where the two fluorine atoms are trans to each other.

Question 7

The most common incorrect answer was **B**. If the ideal gas equation, $pV = nRT$, is used $n = 9.63 \times 10^{-4}$ moles of gas. Since four formula units of KNO_3 produce eight molecules of gas there were originally $0.5 \times 9.63 \times 10^{-4} = 4.81 \times 10^{-4}$ moles of KNO_3 . It is possible that candidates who chose option **B** used the ideal gas equation correctly but did not subsequently use the stoichiometry given in the equation.

Question 10

The most common incorrect answer was **A**. It is true that the enthalpy change of the reaction is x , however enthalpy change of neutralisation is the value per mole of water formed, so this is $x/2$.

Question 30

The most common incorrect answer was **B**. This suggests that the most difficult decision for many candidates was whether or not compound Z, buta-1,3-diene, can be produced by cracking oct-1-ene. If the carbon chain in oct-1-ene breaks between carbon atoms 4 and 5 then compound Z, buta-1,3-diene, can be one of the molecules produced.

Question 39

The most common incorrect answer was **B**. Candidates found this very challenging and struggled to visualise the other correct monomer. The diagram in the question shows two repeat units. Reading from the left hand square bracket the first three carbon atoms and six hydrogen atoms, CH_3CHCH_2 , are a propene residue. The next six carbon atoms and ten hydrogen atoms, $\text{CH}_3\text{CHCHCHCHCH}_3$, are a hexa-2,4-diene residue. This means that the other monomer is hexa-2,4-diene and the correct answer is **D**.

CHEMISTRY

Paper 9701/12
Multiple Choice

Question Number	Key
1	C
2	A
3	D
4	B
5	C
6	B
7	D
8	B
9	A
10	D

Question Number	Key
11	D
12	C
13	B
14	C
15	A
16	A
17	B
18	C
19	A
20	B

Question Number	Key
21	D
22	D
23	D
24	B
25	C
26	C
27	A
28	A
29	B
30	B

Question Number	Key
31	A
32	D
33	C
34	A
35	D
36	B
37	C
38	A
39	C
40	D

General comments

This examination paper provided a difficult challenge to the candidates. Most candidates were able to complete the paper within the hour allowed.

Candidates found **Questions 5, 6, 8, 9, 13, 24, 29** and **33** the easiest.

Many candidates found **Questions 7, 17, 26, 28, 32** and **40** to be particularly challenging.

Comments on specific questions

Question 7

The most common incorrect answer was **A**. A gas behaves less like an ideal gas if it has stronger intermolecular forces. Steam has stronger intermolecular forces than ammonia, since steam can form an average of two hydrogen bonds per molecule while ammonia can form an average of one, so the correct answer is **D**.

Question 17

The most common incorrect answer was **A**. This question required candidates to appreciate that $\text{NH}_3(\text{aq})$ contains both OH^- ions and water. The OH^- ions will give a white precipitate with $\text{MgCl}_2(\text{aq})$ and the water will give a white precipitate with $\text{SiCl}_4(\text{l})$.

Question 26

The most common incorrect answer was **B**. The structure shown has one chiral carbon atom and two double bonds that give rise to geometric isomers. The total number of stereoisomers is therefore $2 \times 2 \times 2 = 8$. Candidates who chose option **B** may have performed the sum $2 + 2 + 2 = 6$.

Question 28

The most common incorrect answer was **C**. Compound C reacts with hot ethanolic NaOH to produce a mixture of six compounds, not three, since the double bond formed can be in three different places and each of the alkenes formed exists as a mixture of two optical isomers.

In the explanation that follows, the carbon atom bonded to bromine in compound A is called C₁ and the other atoms in the cyclohexyl ring are numbered clockwise. If compound A forms a C=C bond between C₁ and C₆ this alkene exists as a mixture of two optical isomers. If compound A forms a C=C bond between C₁ and C₂ this alkene does not have optical isomers, giving the product mixture described in the question.

Question 32

The most common incorrect answer was **B**. The formation of the given product, starting with a dibromoalkane and ammonia, requires two successive nucleophilic substitution reactions. One of these reactions requires a bromine atom on carbon atom 1 of the chain, the other reaction requires a bromine atom on carbon atom 5 of the chain.

Candidates may have found it helpful to visualise this by redrawing the structure of coniine omitting the N–H group. If they then drew in two bromine atoms on the end of the two bonds that were originally leading to the N–H group, this shows that compound X is D.

Question 40

The most common incorrect answers were **A** and **C**.

- Ethanal has an M_r of 44; it can lose a hydrogen atom to give a fragment peak at $m/e = 43$.
- Propan-1-ol has an M_r of 60; it can lose the OH group to give a fragment peak at $m/e = 43$.
- Propan-2-ol has an M_r of 60; it can lose the OH group to give a fragment peak at $m/e = 43$.

Candidates choosing **A** appreciated the first of these bullet points but not the second and third. Candidates choosing **C** appreciated the second and third of these bullet points but not the first.

CHEMISTRY

Paper 9701/13
Multiple Choice

Question Number	Key
1	D
2	C
3	A
4	A
5	D
6	B
7	C
8	C
9	B
10	A

Question Number	Key
11	B
12	D
13	B
14	D
15	D
16	C
17	A
18	A
19	C
20	B

Question Number	Key
21	B
22	A
23	C
24	A
25	C
26	D
27	A
28	B
29	C
30	C

Question Number	Key
31	D
32	A
33	B
34	D
35	C
36	D
37	B
38	A
39	B
40	C

General comments

This examination paper provided a suitable but difficult challenge to the candidates. Most candidates were able to complete the paper within the hour allowed.

Candidates found **Questions 2, 10, 13, 17, 23, 26, 28, 37** and **39** the easiest.

Many candidates found **Questions 9, 12, 15, 22** and **38** challenging.

Comments on specific questions

Question 9

The most common incorrect answer was **C**. The enthalpy change of equation **C** will equal to four times the average bond energy of the C–H bond in methane. Equation **B** is exactly one quarter of equation **C**, therefore equation **B** is the correct answer.

Question 12

The most common incorrect answer was **B**. Three moles of $K_2Cr_2O_7$ contains six moles of chromium(VI). This is reduced to six moles of Cr^{3+} by the gain of 18 moles of electrons. This oxidises 18 moles of I^- ions to give nine moles of I_2 . This is reduced back to I^- ions by 18 moles of $S_2O_3^{2-}$ ions. Candidates who chose option **B** may not have appreciated the importance of the statement in line one that three moles of $K_2Cr_2O_7$ were involved.

Question 15

The most common incorrect answer was **C**. Candidates found this a particularly difficult question. Key pieces of information were:

- Diagrams 1 and 3 can be interpreted to conclude that experiment 2 occurs at a lower temperature than experiment 1.
- Since the reaction goes to completion, and experiments 1 and 2 use identical amounts of X and Y, the total number of moles of gas present after the reaction is complete is the same in experiments 1 and 2.

Two conclusions then had to be drawn:

- Since experiment 2 occurs at a lower temperature the initial rate is slower in experiment 2 than the initial rate in experiment 1. This means lines **A** and **B** are incorrect.
- The lower temperature in experiment 2 causes a reduction in the volume of the gas present after the reaction is complete, therefore the correct line is **D**.

Question 22

Choices **B**, **C** and **D** were all chosen by an approximately equal numbers of candidates. Aqueous sodium iodide is colourless; the chlorine oxidises iodide ions to iodine molecules. Iodine gives an aqueous solution which is coloured yellow or brown depending on concentration, so **A** and **B** are possible correct answers. The iodine molecules formed are non-polar, therefore they are soluble in a non-polar solvent such as hexane. This causes a colour change in the upper hexane layer. In fact, a solution of iodine in hexane is a purple colour. The correct answer is therefore **A**.

Question 38

The most common incorrect answer was **C**. To produce a carboxylic acid group starting with compound C would require acidic hydrolysis of the nitrile group, for example by boiling under reflux with $H_2SO_4(aq)$. However, this would leave the OH group unchanged, producing $CH_3CH(OH)COOH$ and not CH_3CH_2COOH as required by the question.

To produce a carboxylic acid group starting with the compound in **A** would require oxidative cleavage of the alkene group. This can be achieved by heating with hot concentrated acidified $KMnO_4$. This reaction produces CO_2 and $HOOCH_2CH_3$ and so this is the correct answer.

CHEMISTRY

Paper 9701/21
AS Level Structured Questions

Key messages

- Candidates are reminded to read questions carefully and check answers thoroughly, especially in extended answers where more detail is required: the accurate use of chemical terminology is encouraged, as it removes ambiguity from responses. Clear statement of fact is crucial in the presentation of argument, and it is advised that only a narrow range of vocabulary be permitted when assessing understanding.
- Candidates are reminded to address ‘explain’ questions fully and not merely to state facts or rules of thumb, but to show how these combine to give reasons for chemical phenomena. This often requires a secure understanding of bonding and structure within molecules, in particular for organic species, linking structural feature to mechanistic probabilities.
- Candidates are reminded that their working in calculations should be shown to ensure that due credit can be awarded. Harsh or early rounding of numbers should be avoided, as it leads to sizable inaccuracies later.

General comments

This paper tested candidates’ knowledge and understanding of important aspects of AS Level Chemistry. Candidates showed themselves able to perform well on both AO1 knowledge and understanding and AO2 handling, applying and evaluation information items. It was observed that many candidates seemed less familiar with concepts in this session compared to recent similar sessions.

Candidates ought to be clear about the difference between items that ask them to *state* information, and those that ask them to *explain*: in this latter case, it is not sufficient to quote a ‘rule’ by way of evidence: proper reasoning needs to be incorporated into an answer.

Scripts were generally clear and well presented. As a general point of presentation, it is difficult to read scripts where answers written in pencil have been overlaid with ink without rubbing out the pencil. Papers should be cleaned of debris from erasers, as this too affects the legibility of responses. Candidates should be able to write all answers in the spaces provided on the examination paper without the need for additional paper.

Comments on specific questions

Question 1

Many parts of this question were built on the foundations of the subject. Candidates were able to answer many of these parts well.

- (a) The question asked candidates to identify the *highest energy* occupied orbital, hence the requirement for 4s.
- (b) (i) Candidates performed poorly at balancing equations.
(ii) Many candidates were not precise with their explanations.

- (c) Some candidates did not identify the colour of the precipitate formed.
- (d) (i) This was well answered by most candidates.
(ii) This was well answered by many candidates.
- (e) (i) Most candidates seemed unfamiliar with this defined unit of mass.
(ii) This was well answered by most candidates.
(iii) Many candidates were able to give a basic definition of isotopes, though were then unable to develop their answers to detail what effect this would have on the physical and chemical properties of the magnesium isotopes.
- (f) (i) This was clearly a familiar observation to most candidates.
(ii) This question was frequently misinterpreted. Candidates confused ΔH_r and E_a , thus incorrectly giving endothermic profiles.

Some diagrams were unclear and messy. The best answers had the arrows for ΔH_r and E_a starting/ending level with the appropriate points on the diagram. Many answers showed only vaguely referenced energy changes.
- (g) Few answers referenced the change in frequency of successful collisions resulting from an increase in energy.

Question 2

This inorganic and physical chemistry question based around nitrogen was the least confidently answered of the four, although some individual items were handled well by candidates.

- (a) Candidates were variously able to access different parts of this item, though few managed to secure the full allocation of 3 marks. Answers showed knowledge of hybridisation, though fewer were able correctly to identify the sp hybridised atomic orbitals of nitrogen. Otherwise, candidates were able to recall the one sigma (σ) and two pi (π) bonds exhibited in a triple bond. Few candidates were able to recall the precise modes of orbital overlap.
- (b) (i) Recall of VOCs and of PAN were good, with many able to link the creation of one from the other.
(ii) Many answers focused solely on nitrogen and did not reference the cross redox process involving CO/CO₂ and NO_x/N₂.
- (c) This question was answered well by many candidates.
- (d) (i) This question was answered well by most candidates.
(ii) Better performing candidates included a suitable base and conjugate acid in their answers.
(iii) This topic seemed little understood by candidates, with the large majority giving answers that bore no relevance to titration curves. This topic is newly added to the AS syllabus and it is clear that familiarity is yet to be fully established.

Question 3

Much of this organic chemistry question was based on recall of key topics and features. Some extended writing was required from (c)(iii) onwards, although the best answers were concise. Candidates who wrote at greatest length often contradicted themselves.

- (a) The C=C bond proved a common distractor for candidates, who missed the chiral carbon at the β -position in the chain.

- (b) This reaction seemed unfamiliar to many candidates. Those who correctly identified the cleavage of C=C then neglected to continue to oxidise the aldehyde group(s) in the larger fragment to COOH.
- (c) (i) Many candidates answered this well, using either LiAlH₄ or NaBH₄. Candidates are advised to avoid using non-specific or hybrid reducing agents.
- (ii) This reaction is a standard electrophilic addition of H₂O(g) across C=C, using appropriate acidic conditions.
- (iii) Many answers were imprecise and unclear, particularly when candidates had misidentified **R** as the major product. The best answers were clear to include accurate comparisons of carbocation stability, of the extent of substitution of the C⁺ centre and of the different positive inductive effect.
There was some misidentification of **Q** and **R** as secondary and primary respectively.
- (d) (i) Candidates who focused on the alcohols were able to gain some but not all credit, as the answers neglected to reference the oxidation in both cases of the aldehyde groups. The observations for both molecules are therefore identical.
- (ii) Many candidates omitted the inorganic products of the reaction, despite having correctly identified the organic product.
- (iii) Candidates were able to answer this with reference to the reaction with water and included an equation to show the reaction of PCl₅ with water.

Question 4

This question included a mixture of quantitative and qualitative organic chemistry. Candidates were required to use deductive skills to identify compounds **V–Z**. Candidates are urged to use all information given to them: whereas some ostensibly credible answers were offered in (c)(iii) and (d), many efforts were in vain as they had neglected key information such as the class of compound involved.

- (a) Many candidates answered this well, although a large proportion did not complete the question and left the answer as an empirical formula (C₉H₁₆O rather than C₁₈H₃₂O₂). Some answers incorrectly used atomic numbers rather than atomic masses, which was seen with an incorrect ratio compared to hydrogen atoms.
- (b) (i) Many candidates misread the question and gave answers referring to carbonyl groups. Answers that gave correct but non-exclusive tests and observations for carboxylic acids (e.g. Na/effervescence) gained some credit.
- (ii) Candidates needed to show the stoichiometric ratio of 3.196 g of Br₂ to 2.800 g of **V** in order to gain credit.
- (c) (i) Candidates' attention is drawn to the request to name the functional group.
- (ii) Candidates needed to give the formula.
- (iii) The requirement for skeletal formulae led to some candidates' miscounting carbon atoms in the chain. Earlier in the question, it had been stated that **W** is an aldehyde, so structures with the CHO group were expected.
- (d) Fragments need to be positively charged to be observed in a mass spectrum. **Z** needed to be identified unambiguously by structural formula or name.

CHEMISTRY

Paper 9701/22
AS Level Structured Questions

Key messages

- Candidates should be encouraged to use chemical terms with precision and in appropriate contexts.
- Details given in questions need to be read carefully and considered before constructing a response.
- Candidates are expected to use the data provided in the question booklet to the number of significant figures given. Final answers should be given to the number of significant figures appropriate to the data provided.

General comments

Responses were generally clear and well presented. The most successful candidates demonstrated an excellent knowledge of all topics assessed. They recalled and applied relevant knowledge accurately. Candidates who performed less well demonstrated some knowledge and understanding of topics but did not always apply them specifically.

There was evidence of gaps in the basic knowledge and understanding expected at this level from candidates who performed less well.

Comments on specific questions

Question 1

- (a) The structure and bonding of magnesium was well known. Only the very best responses related this knowledge to explain the high melting point and electrical conductivity of magnesium. Reference to the ability of delocalised electrons to move through the structure was rarely seen.
- (b) (i) Correct identification of the oxidation numbers was common.
- (ii) The best responses identified this reaction as ‘redox’ and then explained this answer in terms of electron transfer and/or changes in oxidation number for both species involved. Weaker responses were incomplete.
- (iii) Many definitions did not refer to the standard state of the elements used to make one mole of compound. Reference to ‘standard conditions’ was seen even though the two terms are not equivalent.
- (iv) This calculation proved to be demanding. Many answers calculated the amount of energy released per mole of magnesium used. A much smaller proportion linked the definition of standard enthalpy of formation to the question and used the appropriate stoichiometry of the relevant equation to find the energy released when 1 mol Mg_3N_2 was produced. A significant proportion of final answers did not have a negative sign associated with the value for ΔH .

Inappropriate use of significant figures was also seen, including use of 24 rather than 24.3 for the relative atomic mass of magnesium given in the Periodic Table.

Question 2

- (a) Many answers used the information given to predict the giant ionic lattice structure of radium chloride.
- (b) A significant proportion of these who answered (a) as 'giant ionic' represented a covalently bonded molecule rather than a formula unit showing the appropriate ions.
- (c) (i) The correct formula for radium hydroxide was described correctly in some answers. Some equations did not include the formation of hydrogen gas and not all equations were balanced correctly. The production of radium oxide as the radium containing product was seen even though the radium was added to an excess of water.
- (ii) The more reactive element was frequently identified. Answers that described how the observations would differ were less common. The best answers compared the time taken for a specific and measurable event common to both experiments to occur. Those who described 'more bubbles' needed to qualify their answer in terms of the rate of production of bubbles because both would eventually produce equal amounts of gas. Weaker answers gave no reference to a specific observation, for example 'it's a more vigorous reaction' or 'more gas is made'.
- (iii) In general, when an explanation of different rates is required, the answer should explain the difference in rate rather than explain why one species is more reactive than another.

Some candidates gave answers that explained why the rates of these reactions differed in terms of the effect of different activation energies and related this to the collision theory. Other candidates explained the different abilities of the two elements to lose valence electrons in terms of electronic arrangement and nuclear attraction.

Excellent answers were seen in a small number of responses using either or both arguments. The majority of answers were vague or confused key details.

- (iv) Some answers did not attempt to suggest pH values for these solutions. Of those that included pH values, not all were greater than 7. Correct reference to the trend in solubility of the Group 2 hydroxides was relatively common. Ambiguity occurred in some answers that used inappropriate use of the terms 'reactants' or 'radium' rather than the specific product responsible for creating the alkaline solution.
- (d) Inappropriate reagents or additional incorrect reactions were seen in some answers, including addition of acid with aqueous ammonia or addition of silver chloride in step 1. The colour of precipitates made on addition of $\text{AgNO}_3(\text{aq})$ and the solubility of these precipitates was sometimes confused.

Some incorrectly described the addition of concentrated sulfuric acid to these aqueous samples.

Question 3

- (a) (i) A significant proportion of answers described the equal rates of the forward and reverse reactions in a reaction mixture at equilibrium. It was less common for answers to include reference to no change in measurable properties.
- (ii) Few answers referred to the state symbols in the equation to give descriptions of the initial colourless gas becoming purple. Incorrect answers included descriptions of a grey solid or a brown gas seen at equilibrium.
- (iii) Correct expressions for the equilibrium constant, K_p , were common. Some answers were given in terms of the concentration of the species rather than their partial pressures.
- (iv) Different creditworthy approaches were used to calculate the correct answer. A common approach found the amount of HI used up to form the equilibrium mixture and then subtracted this value away from the initial amount. Other answers appreciated that, because of the stoichiometry of the equation, the total amount of gas produced did not change, so expressed the amount of HI present in terms of its mole fraction.

A common error seen in calculations was based on the presence of 0.0125 mol of H₂ and I₂, either initially or at equilibrium.

- (b) Many answers correctly calculated the enthalpy change for the reaction given in the equation to find the enthalpy change that occurred for the decomposition of 2 mole of HI(g). A much smaller proportion found the enthalpy change for the decomposition of 1 mole of HI(g), as the question asked.
- (c) The idea that the value of K_p for the thermal decomposition of HI(g) was not affected by increasing pressure was described in a significant proportion of responses.
- (d) (i) Some answers described the production of hydrogen iodide by the addition of concentrated sulfuric acid with sodium iodide as ‘acid-base’. Other responses gave answers like ‘substitution’ or ‘displacement’, which were not specific to this inorganic reaction.
- (ii) Equations that described the production of hydrogen sulfide, sulfur dioxide, sulfur or a mixture of these sulfur containing products along with iodine and water were seen. Not all these equations were balanced correctly.
- (iii) Correct descriptions in terms of the relative strength of the hydrogen halides as reducing agents were seen. Inappropriate use of vocabulary to identify the species which behaves as the reducing agent was seen in weaker answers. The weakest responses described the hydrogen halides as oxidising agents.

Question 4

- (a) (i) Many answers gave appropriate structures to represent 1-bromobutane and 2-bromobutane. Structural formulae did not always contain the correct number of bonds around each carbon atom or did not show all the hydrogen atoms at the end of each ‘bond’.
- The correct name 2-bromobutane was seen frequently. Many answers did not identify the number of the carbon atom that the bromine was attached to in 1-bromobutane.
- Some candidates did not use the information given in line 1 of the question and gave branched chain isomers as their structures.
- (ii) Identification of the correct type of structural isomerism was seen. The weakest responses identified stereoisomerism, optical and cis-trans isomerism instead of an example of the type of structural isomer.
- (b) (i) Correct identification of the chiral centre on the halothane molecule was common.
- (ii) Confusion of the terms ‘homolytic’ with ‘heterolytic’ was seen in equations that produced ions rather than free radicals. Some answers did not use the information given in the question stem and gave equations that did not break the C–Br bond.
- (iii) The majority of answers represented the arrangement of electrons in the orbitals in a bromine atom.
- (c) (i) Representation of the monomer used to make polymer X by interpretation of the skeletal formula of its polymer proved demanding. A common error was addition of extra methyl groups at either end of the monomer molecule.
- (ii) ‘Non-biodegradability’ was the most common answer.

Question 5

- (a) The reaction types were usually described correctly. The reagent for reaction 1 was sometimes identified as water even though this reaction is extremely slow, and it is more appropriate to heat the organic reagent with an aqueous alkali. Identification of the reagent as ammonia in reaction 2 was well known. Suitable conditions were often incomplete or incorrect. Confusion regarding use of the term 'reflux' was seen in many answers.
- (b) Vague references to the iodine bond or bromine bond were relatively common. Better answers described the relative strength of the carbon-halogen bond as key to the difference in rate. The best answers linked the difference in carbon-iodine bond strength to the faster rate of reaction by referring to activation energy.
- (c) (i) The mechanism was well known by some. Ambiguous answers were seen in some diagrams that did not clearly show the start point of the curly arrow or the place that the arrow points to. Omission of the lone pair of electrons on the carbon atom of the nitrile group was common.
- (ii) The products made for this reaction was not well known. Some equations did not include H^+ or $\text{HC}/(\text{aq})$ as a reagent while others produced hydrogen cyanide as a product.
- (iii) Representation of this reduction reaction proved demanding for many. Some equations did not show water as a product in the reaction while other equations which showed the correct species were not balanced.
- (iv) Identification of a reducing agent was seen in many responses. A common incorrect answer stated the weaker reducing agent sodium borohydride.

Question 6

- (a) Appropriate knowledge of alkenes was used by many to give relevant observations for the addition of bromine solution. An appropriate observation for the addition of solid sodium carbonate to **Z(aq)** was seen less frequently.
- (b) Clear answers to show the empirical formula of **Z** as CHO were shown.
- (c) (i) This question proved to be demanding. Inclusion of relevant deductions, as outlined in the question stem, was essential. A relatively small proportion of answers included this detail. Answers that stated the molecular formula with no explanation were also seen.

Some candidates were unable to identify the molecular ion peak.
- (ii) Correct identification of the fragment responsible for the peak at 45 was more common than the peak at 71. No charge or a negative charge was shown on the fragments in some answers.
- (iii) Successful candidates considered all the relevant information to deduce an appropriate structure. Incorrect structures were seen in molecules that were constructed using the incorrect valency for carbon, hydrogen and oxygen; did not have an empirical formula, CHO; did not have a molecular mass of 116, or did not contain both an alkene and a carboxyl functional group.

CHEMISTRY

Paper 9701/23
AS Level Structured Questions

Key messages

- There were still many instances where candidates failed to carefully read the question(s) and understand what was being asked. Many responses gave the impression that the question(s) were only scanned and not read in depth to recognise the clues given, in the questions, to guide the candidates towards creditworthy answers.

General comments

Units are an important feature of chemical calculations and should be presented as a single unit and not as a fraction, e.g. $\text{mol}^2 \text{dm}^{-6}$ and not $(\text{mol}/\text{dm}^3)^2$.

The accuracy of mechanisms for organic reactions requires much improvement, specifically associated with the inaccurate use of curly arrows.

Comments on specific questions

Question 1

- (a) Many candidates appreciated that the definition of *ionisation energy* required an input of energy to remove an electron from each atom in one mole of gaseous atoms.

The most common error included removing an electron from one mole of gaseous atoms rather than from each atom (in one mole of gaseous atoms).

- (b) The large increase in ionisation energy from the sixth to the seventh value, in the table of ionisation energies, led most candidates to deduce that element A belonged to Group 16.

- (c) Although the nuclear charge of sulfur is larger than that of phosphorus, the first ionisation energy for sulfur is lower than that of phosphorus. The spin-pair repulsion of two electrons in a 3p orbital of sulfur outweighs this increased nuclear charge.

Many answers quoted the electron configurations of both S and P but did not go on to explain that the $3p^4$ configuration of S contained a pair of electrons in one p-orbital.

- (d) Both Al^{2+} and Na have the same electron configuration of $1s^2 2s^2 2p^6 3s^1$.

The question states that an Al^{2+} ion has a stronger nuclear attraction; this is due to the Al^{2+} having greater nuclear charge / more protons in the nucleus.

Several answers stated that Al^{2+} and Na both have the same number of electrons but missed the key point that the third ionisation energy of Al^{2+} and first ionisation energy of Na both involve the removal of an electron from the 3s orbital.

- (e) The majority of answers gave the correct atomic number of 29 for the copper-65 isotope and recognised that the nucleon number was 65, giving a difference of 36 for the number of neutrons. However, the electronic configuration of copper of $1s^2 2s^2 2p^6 3s^2 3p^6 3d^{10} 4s^1$ was poorly answered, with the majority of incorrect answers containing the $3d^9 4s^2$ as the outer electron arrangement.

- (f) (i) The table of important values, constants and standards given in the question paper was often overlooked.

Most answers appreciated that the number of atoms in 1.05 g of copper is obtained by multiplying the moles of copper by the Avogadro constant (L). In the table of data L is given as $6.022 \times 10^{23} \text{ mol}^{-1}$; the value from the table in the question paper should be used, however the majority of answers used 6.02×10^{23} .

- (ii) The high melting point and electrical conductivity of copper can be explained in terms of the strong metallic bonds in the metallic lattice which contain delocalised electrons that are able to move and hence carry charge.

It was generally recognised that the high melting point was ascribed to the strong bonding in the metal, but the conductivity was less well explained. Many candidates stated there were delocalised electrons but did not appreciate the requirement for the electrons to move throughout the structure for it to conduct electricity.

Question 2

- (a) (i) The upward trend in melting point of Na, Mg and Al was well answered on the sketches; silicon having the highest melting point was often missed and P having the lowest melting point was frequently given in the answers.
- (ii) Both sodium chloride (ionic) and phosphorus(V) chloride (covalent) are solids at room temperature. On addition of water, sodium chloride dissolves to form aqueous Na^+ and Cl^- ions whereas PCl_5 hydrolyses to form phosphoric(V) acid and fumes of $\text{HCl}(g)$. The resulting pH of the solutions will thus be 7 for NaCl and between 0–3 for PCl_5 . Many candidates gave incorrect answers ranging from an acidic pH for NaCl to a gaseous state for PCl_5 .
- (b) (i) The equation representing the chemical behaviour of the Group 17 element, Tennessine, Ts, when NaTs is reacted with bromine, was quite well answered. The major error was the use of Ts for the element instead of Ts_2 , in the equation.

The redox explanation of this reaction was less well answered, with many candidates stating that it was a displacement reaction on the basis that the more reactive element displaces the less reactive halogen. The question required an explanation of this displacement behaviour where the bromine being the stronger oxidising agent, caused the Ts^- (in NaTs) to be oxidised to Ts_2 .

- (ii) The stem of the question stated that Ts had metallic properties similar to those of copper. However, many answers still did not relate this to the lattice structure of the crystalline solid Ts being metallic with a melting point significantly higher than those of Cl_2 and Br_2 .

Chlorine and bromine both have simple molecular structures in the solid lattices.

Question 3

- (a) (i) The dot-and-cross diagram of CO containing a triple bond, one of which is a dative bond from the oxygen to the carbon was generally well answered. It was clear, however, that several candidates had not read the stem of the question and presented diagrams containing either 3 normal covalent bonds or a dative bond from the C atom to the O atom.
- (ii) The enthalpy calculation using bond energy values proved challenging for many candidates.

Common errors included omitting the $\Delta H = -7 \text{ kJ mol}^{-1}$, in the calculation, using the expression $\Delta H = \text{bonds broken} - \text{bonds made}$ and using $2 \times$ the bond energy for C–C bond in ethane.

Answers that presented the displayed structures of the ether, ethane and methane to establish which bonds were being broken, tended to gain credit for at least one mark and often full credit.

- (iii) Many answers gave a correct expression for the K_c of the equilibrium mixture formed when $\text{C}_4\text{H}_{10}\text{O}$ is heated in a sealed container.

In this expression, a number of answers summed the products and divided by the reactant and gave incorrect units.

- (iv) It was generally recognised that I_2 behaved as a catalyst when it was added to the reaction involving the thermal decomposition of $\text{C}_4\text{H}_{10}\text{O}$, because the E_a of the reaction was reduced from 224 (without I_2) to 143 kJ mol^{-1} (with I_2).

Many answers incorrectly stated that the numerical value of K_c was changed because the equilibrium position was changed.

I_2 behaves as a catalyst which ensures that the equilibrium is attained faster but its position is not changed and hence, nor is the numerical value of K_c .

- (v) Several poor diagrams representing the Boltzmann Distribution curve for molecules of $\text{C}_4\text{H}_{10}\text{O}$, **G**, at temperature $(T+100)^\circ\text{C}$.

The most common errors included the hump of the $(T+100)^\circ\text{C}$ curve being higher than that of the original curve (at a lower temperature) and more often the line of the curve merging with the original curve.

- (b) (i) This was generally well answered. The type of structural isomerism shown between **G** and **H** was functional as the ether, **G**, did not react with acidified $\text{K}_2\text{Cr}_2\text{O}_7$ but **H** did react.

- (ii) This was generally quite well answered. Both **H** and **J** reacted with acidified $\text{K}_2\text{Cr}_2\text{O}_7$; the type of structural isomerism exhibited by **H** and **J** is positional.

- (iii) Candidates who recognised that **H** and **J** are alcohols tended to gain credit for butan-1-ol and butan-2-ol as possible structures.

Creditworthy answers were less frequent for **H** as butan-1-ol and **J** as butan-2-ol, based on the different boiling points given in the table of data.

- (c) Many correct answers for the displayed formula of propanal were seen.

Question 4

- (a) (i) The mechanism for the electrophilic addition of HCl(g) to 2-methylpropene to give the major product as 2-chloro-2-methylpropane was overall not well answered. Curly arrows representing the movement of a pair of electrons were frequently inaccurate and tended to start from the HCl and point towards the propene analogue, instead of from the π bond to the H of HCl .

Many curly arrows also started from an atom in a covalent bond instead of from the middle of the covalent bond.

- (ii) Explanations for a higher yield of 2-chloro-2-methylpropane (in (a)(i)) than the 1-chloro-analogue tended to mention that an inductive effect was involved due to the presence of methyl groups, but the correlation between these two factors was often not mentioned.

The greater yield of the 2-chloro-halogenoalkane is linked to the more stable intermediate tertiary carbocation and not the ‘more stable halogenoalkane compound’, which was frequently mentioned as an incorrect answer.

(b) (i) The functional group present in **T**, formed as a result of the substitution reaction of the two halogenoalkanes (**Q** and **M**) with $\text{AgNO}_3(\text{aq})$ in ethanol, is a hydroxyl/alcohol group. Many correct answers were seen. Common errors included RCOOH and an aldehyde for the functional group and addition and displacement for the types of reaction.

(ii) An ionic equation was required here for the formation of a yellow precipitate when one halogenoalkane, **M**, reacted with $\text{AgNO}_3(\text{aq})$.

Candidates who recognised that the yellow precipitate was $\text{AgI}(\text{s})$ often presented correct answers. Many answers, however, attempted to use **Q** with $\text{AgNO}_3(\text{aq})$, which formed a white precipitate and did not gain any credit.

(iii) The C–I bond, in iodoalkane **M**, is weaker than the C–Cl bond, in the chloroalkane **Q**, and will, therefore, react with the $\text{AgNO}_3(\text{aq})$ and produce a yellow precipitate more quickly.

Many answers gave **Q** as the reagent that acted more quickly.

(iv) When alcohol **T**, derived from the hydrolysis/substitution of $\text{C}_4\text{H}_9\text{X}$ (where **X** = I and Cl), is reacted with alkaline $\text{I}_2(\text{aq})$, a yellow precipitate was formed of tri-iodomethane (CHI_3). The alcohol will contain the $\text{CH}_3\text{CH}(\text{OH})-$ group, within the $\text{CH}_3\text{CH}(\text{OH})\text{CH}_2\text{CH}_3$ molecule, which is responsible for the reaction with alkaline $\text{I}_2(\text{aq})$.

Very few candidates appreciated that the anion formed from this reaction is $\text{CH}_3\text{CH}_2\text{COO}^-$.

(v) The structure of **M**, the straight-chain halogenoalkane, that forms a yellow precipitate with $\text{AgNO}_3(\text{aq})$ in ethanol, is the iodo derivative containing the $\text{CH}_3\text{CH}(\text{I})-$ group.

M is 2-iodobutane, $\text{CH}_3\text{CH}(\text{I})\text{CH}_2\text{CH}_3$.

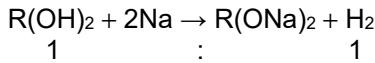
The majority of answers gaining credit gave 1-iodobutane for the structure of **M**, $\text{CH}_3\text{CH}_2\text{CH}_2\text{CH}_2\text{I}$.

Question 5

(a) (i) Cold, dilute KMnO_4 is used to produce a diol, **Y**, which reacts with Na to produce a gas. The majority of answers for the conditions for this reaction ranged from room temperature and pressure to aqueous and acidified. There were very few answers giving the correct conditions.

(ii) The structure of **Y** is butane-1,2-diol, $\text{CH}_3\text{CH}(\text{OH})\text{CH}(\text{OH})\text{CH}_3$. The information in the question stated that 24 dm^3 of gas is produced (under room conditions) when excess Na is added to 0.001 mol of **Y**.

The moles of $\text{H}_2(\text{g})$ (0.001) produced from **Y** (0.001) is a 1 : 1 ratio, so there are 2OH groups for every Na.



A few answers correctly gave the structure of butane-1,2-diol but the explanation using the information of the gas produced from a quantity of **Y** was rarely seen.

(b) (i) The expression $n = \frac{100 \times \text{abundance of } (\text{M}+1)\text{ ion}}{1.1 \times \text{abundance of } \text{M}^+\text{ ion}}$ using the relative abundances of the M^+ and $(\text{M}+1)$ ions, in the mass spectrum, to determine the number of carbon atoms in the molecule of **Z** was rarely used. The spectrum provided a ratio of 100 : 2.2 for the M^+ and the $(\text{M}+1)$ ions respectively leading to a value of $n = 2$, for the number of C atoms in **Z**.

(ii) Very few candidates were able to deduce the presence of the chlorine atom in **Z**.

The relative abundance of the M : M+2 peaks is 100 : 33.3 (from the spectrum); it can be deduced from this ratio that these peaks represent the molecular ion with $35-\text{Cl}$ and $37-\text{Cl}$ respectively.

- (iii) Many of the few answers that attempted to deduce the formulae of the fragments at $m/e = 29$ and $m/e = 49$ did not include a positive charge on each ion.

A molecule of **Z** contains two C atoms and a Cl atom and the fragments at $m/e = 29$ and $m/e = 49$ are $C_2H_5^+$ and CH_2Cl respectively, leading to chloroethane as the name of **Z**.

CHEMISTRY

Paper 9701/31
Advanced Practical Skills 1

Key messages

- Candidates should be reminded to read the information given in each question so that they can record suitable results and apposite answers.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.
- Candidates and supervisors must enter the information regarding session and laboratory on the front cover of the examination paper so that candidates' results can be matched with those of the relevant supervisor.
- Centres should be aware that the identities of chemicals given in the question paper may differ from those given in the confidential instructions. This is not an error and a statement to this effect is written in the confidential instructions.

General comments

Many candidates appeared to have only limited experience of some practical skills and in discussing their underlying chemistry. Most were familiar with the demands of **Question 1**, a titration-based problem. In **Question 2**, a thermal decomposition, while candidates seemed to carry out the practical well, many could neither present their results to the standard required nor cope with the calculations and questions testing their understanding of the reactions and processes occurring. **Question 3** responses varied widely: some candidates made accurate, succinct observations and selected suitable reagents for further tests to allow the identification of the unknown substances. Others struggled in choice and execution of tests.

There seemed to be no time constraints, as very few candidates were unable to finish the paper.

Comments on specific questions

Question 1

The majority of candidates appeared well prepared in the basic technique of titration although in some centres more practice in actually carrying out the exercise as well as recording and analysing data would have helped greatly.

- (a) Many candidates demonstrated the ability to obtain concordant results and present them as required. A common omission was the recording of the burette readings for the rough titre. These need not be shown to the same level of accuracy as those for the accurate titres, but some numbers should be shown. Some candidates carried out extra titrations when they already had suitable results.
- (b) The majority of candidates were able to select titres with a total spread of 0.20 cm^3 and give the answer correct to 2 decimal places.
- (c) (i) Almost all candidates successfully calculated the amount of sodium hydroxide in the mean titre, correct to 3 or 4 significant figures.

- (ii) Most candidates realised that the calculation of the relative formula mass involved using the mass and the number of moles but a large number did not take into account the different volumes used. This error gave an answer that was 40 times too large. Candidates should perhaps have realised that such a large relative formula mass was unlikely.
 - (iii) The acid chosen had to correspond to the relative formula mass calculated in (ii) and many candidates named and drew correct formulae. Only a small number drew formulae other than the skeletal one required.
- (d) (i) A number of correct equations were seen but a significant number gave an incorrect formula for the product or gave incorrect / missing state symbols.
- (ii) Many candidates correctly stated that the student's titre would be larger but only the better responses included an acceptable explanation. It was necessary to comment on the effect that the different relative formula masses would have.

Question 2

Candidates should be reminded to use the same balance for all their masses. Two decimal place balances are suitable but one decimal place balances are not. Some of the responses to (b)(ii) to (b)(iv) showed that many candidates could not interpret the chemistry involved in the decomposition.

- (a) A large number of candidates gained some credit for accuracy in this experiment. However, a significant number of candidates incorrectly labelled the residue in the crucible after heating as **FA 4**. Some candidates omitted the mass of residue and / or the mass lost in their tables, whilst others confused the two masses. A few candidates did not heat the crucible and contents for a second time so were unable to access some of the credit available for this part. The results obtained by some candidates suggested they were attempting to heat with spirit burners – these are unsuitable for this decomposition.
- (b) (i) Most candidates correctly calculated the number of moles of magnesium oxide.
- (ii) A significant number of candidates also correctly calculated the relative formula mass of **X**.
- (iii) Since the introduction to the question stated that the compound decomposed to give magnesium oxide and **X**, and that **X** contained one or more oxygen atoms, the most likely conclusion was that **X** was carbon dioxide or water.
- (iv) Most candidates who correctly identified **X** deduced the identity of **FA 4**.
- (c) Many answers were based on the idea that a lid would prevent gases escaping or encourage water to be retained. Neither of these was accepted, as the answer should have involved observing the solid when it was being heated and stating that a lid would improve the accuracy if the solid had frothed or spitting occurred on heating but would not improve it if neither phenomenon was noted.
- (d) This proved challenging since only a minority of candidates understood that the uncertainty of a balance reading needed to be multiplied by 2.

Question 3

Some candidates followed the introductory instructions and performed well but others used inappropriate words to describe their observations and / or chose incorrect reagents when suggesting tests for unknown ions. Reading through the tests to be carried out before starting any practical work would focus the candidates' minds on the type of reactions that are feasible and what they might observe.

- (a) (i) A suitable table would have included correct headings to show the reagent being used and an accurate description of the observations made. A number of candidates did not give the correct name or formula of reagents.

A complete answer to this part would involve tests for all the possible ions that contain nitrogen. Most candidates chose to use aqueous sodium hydroxide but many appeared confused whether, in a particular test, they were adding aluminium or not. It was necessary to do both to distinguish between an ammonium compound and nitrate / nitrite.

- (ii) Many candidates only noted that the solid melted and this alone was insufficient to gain credit.

- (b) (i) Most candidates did not give precise enough answers. In observations it should be noted whether a colour change is seen or whether the colour merely remains. If no reaction is seen this should be recorded as 'no visible change'.

- (ii) Since the question asked that formulae should be given, full credit was not available if only names were stated.

A significant number of candidates gave $\text{Al}_2(\text{SO}_4)_3$ but few gave both KI and I_2 .

- (iii) Few candidates gave a correct ionic equation. Most gave incorrect formulae, did not balance the equation or omitted the state symbols.

CHEMISTRY

Paper 9701/32
Advanced Practical Skills 2

Key messages

- Candidates should be reminded to read the information given in each question so that they record suitable results and apposite answers.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.
- Candidates and supervisors must enter the information regarding session and laboratory on the front cover of the question paper so that candidates' results can be matched with those of the relevant supervisor.
- Centres should be aware that the identities of chemicals given in the question paper may differ from those given in the confidential instructions. This is not an error and a statement to this effect is written in the confidential instructions

General comments

Overall many candidates appeared to have had only limited practice in some of the techniques and in discussing their underlying chemistry. Most were familiar with the demands of **Question 1**, a titration-based problem. In **Question 2**, while candidates seemed to carry out the practical work well, greater discussion of how to present results graphically would have aided candidates. Also, many could not cope with the calculations and questions checking their understanding of the processes occurring. **Question 3** responses varied widely: some candidates chose and described a correct test to identify the anion in **FB 6** and then made accurate, succinct observations in **(b)** whilst others struggled. There seemed to be no time constraints as very few candidates were unable to complete the paper. There were very few candidates with very high marks.

Comments on specific questions

Question 1

The full range of marks was awarded for this question.

- (a)** Many candidates presented their results as required and demonstrated the ability to obtain concordant results. A common omission was the recording of the burette readings for the rough titre. These need not be to the same level of accuracy as those for the accurate titres, but some numbers should be shown. A number of candidates gave the burette readings for their accurate titres to one decimal place rather than to the nearest 0.05 cm^3 . A minority of candidates carried out an unnecessary additional titration after they had obtained concordant titres.
- (b)** The majority of candidates were able to select titres with a total spread of 0.20 cm^3 , show their working and give the mean titre correct to two decimal places.
- (c) (i)** Many candidates successfully presented all their answers to three or four significant figures.
- (ii)** The majority of candidates correctly calculated the amount of sodium hydroxide titrated. Most candidates then deduced that the moles of sodium hydrogen sulfate present in 25.0 cm^3 of **FB 2** was equal to the moles of sodium hydroxide.

- (iii) Only a minority of candidates carried out both steps required for this question. Most multiplied their answer for (c)(ii) by the formula mass of sodium hydrogen sulfate but few also multiplied by 40 ($1000 \div 25$).
- (iv) Several different methods were used by candidates to calculate the percentage purity successfully. A minority of candidates wrongly calculated the percentage error.

Question 2

Few candidates performed very well on this question. Candidates were rarely awarded full credit for the graph. The calculations in (c) were often completed unsuccessfully. Candidates should be encouraged to check their working if their answer differs widely from that expected.

- (a) Thermometers are calibrated at 1 °C so should be read to the nearest 0.5 °C. A significant minority of candidates recorded the readings as integers or to 0.1 °C. Some candidates incorrectly recorded thermometer readings as 0.00 or 0.50 °C. Many candidates gained some credit for accuracy.
- (b) (i) It was rare that full credit was awarded in this part. Common errors included starting the scale for the y-axis at 0 °C or omitting room for the 2 °C above the highest maximum temperature. Most candidates selected scales that were easy to employ but then did not plot points sufficiently accurately to gain credit. If a point should be on a line, then the centre of that point must be on the line. Candidates should be encouraged to sharpen their pencils before plotting a graph so that one line in a 'x' does not occupy over half a small square. Where necessary, only a minority of candidates correctly identified anomalous points. Few succeeded in drawing both lines of best fit suitably. Such lines should have points balanced either side of the line and not be capable of rotation. Lines can be curved or straight. Many candidates drew a straight line for the rise in temperature when their plotted points clearly indicated a curve was required.
- (ii) Most candidates read the volume at the intersect correctly. A number of candidates reported the maximum temperature rather than the change in temperature. Some candidates calculated ΔT from Table 2.1 rather than from the graph.
- (c) (i) Almost all candidates answered this question successfully. A small number gave their answer to one significant figure. Candidates should always consider how many significant figures are suitable when recording the final answer for a calculated value.
- (ii) Most candidates knew the formula to use and gave a correct value for ΔT . Use of either ΔT from (b)(ii) or calculated from Table 2.1 was acceptable. However, very few candidates used the correct mass in their calculation, failing to include the mass of **FB 4** as well as the value for **FB 5** obtained from the graph. Centres are reminded that the value of the specific heat capacity, c , is now provided in the important values, constants and standards table towards the end of the paper.
- (iii) Even when candidates had an incorrect value in (c)(ii) they were able to gain credit owing to error carried forward. Almost all candidates showed their answer had a negative value, but the unit given by a small number of candidates did not match the magnitude of the numerical answer because it was incorrect by a factor of 1000. The most common reason credit was very rarely awarded was that the factor of 2 required in the calculation (as sulfuric acid is diprotic) was omitted.
- (d) (i) Many candidates chose to use the default value and correctly calculated the percentage error. Common errors were not finding the difference in values or using the incorrect denominator.
- (ii) A significant number of candidates ignored the instruction in the question and suggested the use of a lid or insulation. Those that did suggest taking more readings often did not give enough explanation as to how this would improve the determination of the intersection point on the graph. Discussion of ways of improving experimental procedures should be part of the teaching of the practical element of the AS and A level courses.
- (e) (i) A number of candidates who did not use the factor of 2 in their calculation for (c)(iii), correctly did so for this question.

- (ii) For this question, candidates needed to consider the effect that the different concentration of **FB 4**, and therefore **FB 1**, would have on the titre value and/or the subsequent calculation of results. Many candidates ticked the middle box and stated that the NaHSO_4 had not actually changed and therefore the percentage purity would be the same, which is not sufficient explanation.

Question 3

Candidates need to take note of the instructions above the start of the tasks, for example, giving both colour and state of the products of a reaction. Care with language is needed as ‘clear’ is not the same as ‘colourless’, ‘cloudy’ is not the same as ‘precipitate’ and a ‘cloudy solution’ does not exist. It is useful for candidates to read through the tests to be carried out and to consider the possible outcomes of each before starting the practical work.

- (a) Most candidates gained some credit for this part. Almost all candidates selected at least one suitable reagent, but a number did not then carry out the test and others did not select the second reagent, if required. For example, if (aqueous) silver nitrate was selected (aqueous) ammonia was also required to determine which halide ion was present. Some candidates gave an incorrect formula such as $\text{Ag}(\text{NO}_3)_2$ or Ag^+ . Candidates who chose to test for a halide ion usually did not state that the **FB 6** solid needed to be made into a solution before use. Those who chose to test for carbonate rarely described how any gas evolved is tested with limewater.
- (b) (i) A wide range of performance was seen to this part. For **Test 1**, candidates should consider what happens to the colour of the aqueous acidified potassium manganate(VII). With **FB 8**, the potassium manganate(VII) is decolourised but a large number of candidates stated ‘no change’. Candidates are told that all the cations they are testing for are listed in the Qualitative analysis notes. It would have helped candidates to refer to these whilst they were doing **Tests 2** and **3**. Acceptable initial colours of precipitate for the reaction of **FB 7** with alkali are off-white or pale brown but this was often missed even when a final brown colour was reported. Similarly, the initial colour of precipitates formed with **FB 8** were often incorrectly reported as blue or blue-green or grey-green, even when the precipitate was reported to later turn brown. Candidates should always report the solubility of precipitates in excess alkali. Some candidates did not realise the purpose of warming the mixtures in **Test 3** and did not use litmus paper. Many candidates reported that litmus turned blue with **FB 7** but did not mention that this happened when the litmus was exposed to gas so could not be awarded credit as they might have placed the litmus in the alkaline mixture.
- (ii) Candidates should have read the information provided at the top of the page. Some identified more than three cations or ions which do not appear in the Qualitative analysis notes.
- (iii) This was a challenging question for candidates and very few gained credit. Few candidates realised that the ion reacting in the aqueous ammonia was OH^- . Other errors were not balancing the equation, including spectator ions and omitting state symbols.
- (iv) This was rarely answered correctly. Some candidates recognised that acidified potassium manganate(VII) is an oxidising agent but suggested the type of reaction was oxidation rather than redox. Other incorrect reaction types suggested were substitution, precipitation, displacement, neutralisation and addition.

CHEMISTRY

Paper 9701/33
Advanced Practical Skills 1

Key messages

- Candidates should be reminded to read the information given in each question so that they record suitable results and apposite answers.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.
- Candidates and supervisors must enter the information regarding session and laboratory on the front cover of the question paper so that candidates' results can be matched with those of the relevant supervisor.
- Centres should be aware that the identities of chemicals given in the question paper may differ from those given in the confidential instructions. This is not an error and a statement to this effect is written in the confidential instructions.

General comments

Overall, many candidates appeared to have had only limited practice in some of the techniques and in discussing their underlying chemistry. Most were familiar with the demands of **Question 1**, a titration-based problem. For **Question 2**, a thermal decomposition, while candidates seemed to carry out the practical work well, many could neither present their results to the standard required nor cope with the calculations and questions checking their understanding of the reactions and processes occurring. **Question 3** responses varied widely: some candidates made accurate, succinct observations and chose sufficient tests to identify both ions in **FA 8**, while others struggled. There seemed to be no time constraints as very few candidates were unable to complete the paper. There were few candidates with very high or very low marks.

Comments on specific questions

Question 1

Most candidates appeared well prepared in the technique of titration. Fewer candidates were able to use their results to answer all the questions posed.

- (a) Most candidates demonstrated the ability to obtain concordant results and present them as required. The most common omission was the recording of the burette readings for the rough titre. These need not be to the same level of accuracy as those for the accurate titres but some numbers should be shown.
- (b) The majority of candidates were able to select titres within a total spread of 0.20 cm^3 and give the answer correct to two decimal places.
- (c) (i) Almost all candidates successfully calculated the amount of sodium hydroxide correct to three or four significant figures in the mean titre.

- (ii) Many candidates gained credit for calculating the amount of phosphoric acid in the volume pipetted. The most common error was to omit the factor of 40 which was needed to reduce the mass dissolved in 1 dm³ given in the stem of the question. Some candidates ignored the information given and divided (c)(i) by 3.
 - (iii) Candidates were expected to use their answers to (c)(i) and (c)(ii) to deduce whether the phosphoric acid in the experiment they had carried out was mono, di or triprotic. A common error was to assume the acid was triprotic as the formula suggested three H⁺ ions would be released. However, some candidates gave an excellent explanation of why the acid was diprotic.
 - (iv) The stem of the question still referred to the experiment the candidates had carried out. Hence the equation had to match the proticity deduced in (c)(iii). Few candidates gave this and many candidates were unable to give chemically possible products or to balance the equation.
- (d) (i) The calculation of percentage error was correctly displayed and calculated by the majority of candidates.
- (ii) This question proved challenging to most candidates. Only a minority understood that the uncertainty of a burette reading needed to be multiplied by 2 and explained this.

Question 2

Candidates should be reminded to use the same balance for all their masses. Two decimal place balances are suitable but one decimal place balances are not (as stated in the current syllabus). The responses to (c) and (d) demonstrated the lack of careful reading of the tasks set.

- (a) A large majority of candidates gained some credit for accuracy for this experiment. However, a significant number of candidates incorrectly labelled the residue in the crucible after heating as **FA 4**. Some candidates omitted the mass of residue and/or the mass loss in their tables of results while others confused the two masses. A few candidates did not heat the crucible and contents for a second time so were unable to access some of the credit available for this part. The results obtained by some candidates suggested they were attempting to heat with spirit burners, rather than Bunsen burners (or burners with propane or butane gas canisters), which are unsuitable for this purpose.
- (b) (i) Most candidates answered this correctly. The error usually seen was to give the answer to an unsuitable number of significant figures. One significant figure or more than four significant figures were not acceptable given the accuracy of the balances used.
- (ii) Many candidates performed well here. Errors were the use of the mass of the residue (**FA 5**) rather than **FA 4** or to subtract 60 at this point instead of in (iii). It was obvious from the values of the M_r calculated that decomposition was incomplete and this may have affected candidates' confidence in their working.
- (iii) Most candidates calculated the A_r of metal **M** successfully. However, many did not use the information given in the question to identify **M** correctly. From the equation given at the start, **M** is known to be divalent. As **FA 4** (and **FA 5**) were white, the metal was unlikely to be a transition element. Final answers included Group 1 and transition metals and non-metals.
- (c) While many candidates understood that both water and carbon dioxide would be lost on heating, very few took note that the same mass of solid had been heated. A few candidates gained credit by comparing the formula masses of H₂O and CO₂ but only the best responses went on to compare the mass losses from the carbonate and basic carbonate.
- (d) Almost all candidates noted effervescence on adding acid to their residue. Some tested the gas with limewater and reported the formation of the expected white precipitate. A few candidates incorrectly described the unreacted solid as a precipitate, showing they did not understand this term. Many candidates reporting effervescence went on to state decomposition was complete with some giving the reason that they had achieved constant mass on heating in (a). Candidates should have used their observations in the first part of (d) as fizzing with acid is an indication that carbon dioxide is released, hence the decomposition was incomplete.

Question 3

Candidates need to take note of the instructions above the start of the tasks, for example, giving both colour and state of the products of a reaction. Care with language is needed as ‘clear’ is not the same as ‘colourless’; ‘cloudy’ is not the same as ‘precipitate’ and a ‘cloudy solution’ does not exist. It is useful for candidates to read through the tests to be carried out and to consider the possible outcomes of each before starting the practical work.

- (a) (i) Most candidates were able to gain at least some credit with some performing very well. A common omission was noting the bubbling in **Test 2** with **FA 7**. Testing the gas evolved was very rarely carried out. Another commonly seen error was in **Test 4** with **FA 6** where a dark blue precipitate and/or solution were reported. Almost all candidates were aware that **FA 6** contained Cu^{2+} ions so should also have been aware that the accepted colour of the precipitate is pale blue and that the precipitate is insoluble in excess NaOH(aq) (as given in the Qualitative analysis notes).

It is important that candidates follow the instructions given in the table. When asked to add a few drops, excess should not be added, nor should extra reagents be used even if candidates think these may aid their conclusions.

- (ii) Few candidates gained credit for an appropriate ionic equation. Errors included attempting to write an equation for a test other than **Test 2**, not balancing the equation, including spectator ions and omitting state symbols. Practice is needed for candidates to succeed in this task.
- (b) (i) It was apparent from the answers that some candidates did not heat **FA 8** gently at first so missed the condensation forming on the cooler part of the hard-glass test-tube. Very few continued to test for any gas evolved after finding the red litmus turning blue. Few candidates described the residue or lack of it.
- (ii) There were some excellent answers to this part with clearly headed tables of results and all the expected tests and observations listed. However, some did not heed the instruction that only the tests that positively identified each ion should be recorded. When testing with aqueous sodium hydroxide and warming the mixture it is the gas that must be tested with red litmus paper. Those adding aluminium to the reaction mixture were testing for an anion (NO_3^- or NO_2^-) rather than a cation (NH_4^+), as all three ions would produce ammonia. When testing with aqueous barium chloride or nitrate the solution is added to a solution of the unknown. Hence it was important that **FA 8** was dissolved in distilled water before carrying out this test. When adding acid to the precipitate to distinguish between sulfate and sulfite it is necessary to name the acid; sulfuric acid is not suitable.

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Paper 9701/34
Advanced Practical Skills 2

Key messages

- Candidates should be reminded to read the information given in each question so that they record suitable results and apposite answers.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.
- Candidates and supervisors must enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with those of the relevant supervisor.
- Centres should be aware that the identities of chemicals given in the question paper may differ from those given in the confidential instructions. This is not an error and a statement to this effect is written in the confidential instructions.

General comments

Some candidates seemed lacking in practice of the two methods of quantitative analysis employed in the paper. Some candidates appeared to have difficulty in collecting the gas evolved in **Question 1**. Greater discussion of how to present results graphically would have aided candidates in **Question 2**. **Question 3** responses varied widely: some candidates made accurate, succinct observations and selected suitable reagents for further tests whereas others struggled.

A large majority of candidates completed the paper. There were few candidates with very high or very low marks.

Comments on specific questions

Question 1

It would be helpful if any supervisor collecting a very low (or very high) volume of gas were to repeat the procedure. While most candidates attempted all parts of this question few performed very well.

- (a) The range of gas volumes collected by candidates ranged from single figures to over 250cm³. This is not an easy technique to carry out and allowance is made in the range of volumes to merit accuracy marks. Some candidates reported a gas volume to one decimal place. This is not feasible given the calibration of a 250cm³ measuring cylinder.
- (b) (i) A large majority of candidates gained credit here. Those who did not, usually omitted the factor of 1000 to convert dm³ to cm³ or vice versa.
- (ii) Slightly fewer candidates gained credit. Some omitted the factor of 2 shown in the stoichiometric equation or the factor to convert the amount of hydrochloric acid in 50cm³ to that in 1dm³.

- (c) (i) Many candidates correctly stated that **FB 2** was in excess or that **FB 1** was the limiting factor. However, fewer related the expected observation of unreacted solid being left in the flask. Some of those who noted solid left in the flask incorrectly described the solid as a precipitate.
- (ii) A large minority of candidates either wrote about methods of reducing the solubility of the carbon dioxide instead of answering the question or suggested inappropriate methods. Those who gained credit tended to answer in terms of methods of separating the reactants until the bung was replaced or ways of slowing the production of gas so less was lost before the bung could be replaced. It was clear that some centres had discussed methods of improving practical procedures with their learners.

Question 2

Few candidates performed very well on this question. Even otherwise good candidates tended to perform poorly either in the table of results or in the graphical section. Candidates should be encouraged to check their working if the final answer differs widely from that expected (once the paper is otherwise completed).

- (a) Thermometers are calibrated at 1 °C so should be read to the nearest 0.5 °C. A significant minority of candidates recorded the readings as integers. Most candidates correctly recorded the volumes of **FB 4** and water for experiments 6 and 7 to 0.00 cm³. Discussion of this procedure during the AS level course would have aided candidates in selecting appropriate volumes of **FB 4** and water for these extra experiments. It is helpful to have more information around the volume, first giving the highest maximum temperature. The procedure given in (a) should have resulted in a 'plateau' when graphed but some candidates reported a decrease in maximum temperature on using higher volumes of **FB 4**. A few candidates reported a steadily increasing maximum temperature but neither of these appeared to be centre-wide. Most candidates gained some credit for accuracy.
- (b) It was rare that full credit was awarded in this part. Common errors included starting the scale for the y-axis at 0 °C or omitting room for the 2 °C above the highest maximum temperature. Most candidates selected scales that were easy to employ but then many did not plot points sufficiently accurately to gain credit. If a point should be on a line, then the centre of that point must be on the line. Candidates should be encouraged to sharpen their pencils before plotting a graph so that one line in a 'x' does not occupy over half a small square. Anomalies should occur rarely if the procedure is followed carefully so candidates should have found none, one, or a maximum of one per line. Most candidates identified anomalous points correctly. However, fewer succeeded in drawing suitable lines of best fit. Such lines should have points balanced either side and not be capable of rotation. Most candidates read the volume at the intersect correctly but some did not consider the scale they had used on the x-axis and gave the answer as an integer.
- (c) (i) Candidates generally gave their answers to the expected numbers of significant figures.
- (ii) Most candidates performed well here. There was no penalty for using the default value for the volume of **FB 4** even if the volume was recorded in (b).
- (iii) Most candidates gaining credit in (c)(ii) answered this part correctly.
- (iv) Most candidates used a correct value of ΔT . Fewer candidates included the volume of water and/or **FB 3** in their equation.
- (v) Even when candidates had an incorrect value in (c)(iv) they were able to gain credit owing to error carried forward. Those who did not gain credit generally omitted converting J into kJ. Checking units is a good way of checking working. Almost all candidates showed their answer had a negative value.
- (d) (i) There were many good answers to this part. The most common errors were to divide the value from (c)(v) by 57.6 or to divide the difference in the two enthalpy changes by their answer to (c)(v).
- (ii) A significant number of candidates ignored the instruction in the question and suggested the use of a lid to give a more accurate value for the enthalpy change of neutralisation. Discussion of ways of improving experimental procedures should be part of the teaching of the practical element of the AS and A level courses.

Question 3

There was a very wide range of marks awarded for this question. Some centres appeared to have encouraged their learners to follow the introductory instructions as some good performances were seen. Reading through the tests to be carried out before starting any practical work would focus the candidates' minds on the type of reactions that are feasible and what they might observe.

- (a) (i) Almost all candidates noted effervescence with **FB 5**, **FB 6** and **FB 7** in **Test 1**. However, fewer tested the gas with a lighted splint. Some candidates claimed the gas turned limewater milky. Not only was this impossible, but 'milky' is not an allowed description of a positive result for this test: this should be 'white precipitate'. Very few candidates noted the difference in rate of fizzing for the three acids. **Test 2** relied on candidates appreciating they were testing the unknowns with an oxidising agent. 'Purple (solution)' does not convey whether they are observing the colour of the reagent or the contents of the test-tube after mixing with an acid that could not be oxidised. When there is a change in colour during a test, candidates should quote both the initial and final colours. Very few candidates noted the rapid colour change to colourless with **FB 8** compared with the slower reaction with **FB 7**.
- (ii) There were some excellent answers to this part. However, some candidates suggested **FB 7** was hydrogen peroxide even though they reported bubbling with magnesium in (a)(i). While the lack of effervescence with magnesium was sufficient to identify hydrogen peroxide, the correct observations of both tests was needed to distinguish methanoic acid from the other two acids. A few candidates ignored the information given and selected compounds that were not listed in (a).
- (iii) Most candidates gained some credit in this part. Suitable reagents were selected by nearly all candidates but some did not then carry out the test. Some candidates gave incorrect formulae of reagents such as 'BaCl₁' or 'Ag⁺'. Candidates who did not record the result of their test could not gain full credit. However, the majority of candidates were successful.
- (iv) Very few candidates gained credit here. Common errors included writing an equation for a different reaction, including spectator ions and omitting state symbols. As **FB 5** had been identified as an acid in (a)(i) the reaction should have been between Mg(s) and H⁺(aq).
- (v) Almost all candidates successfully described the reaction to be expected between magnesium and ethanoic acid. However, far fewer candidates appeared to know that ethanoic acid cannot be oxidised under the conditions specified in (a)(i).
- (b) Many candidates gained full credit here. Those who did not either omitted testing **FB 9** with excess of the alkalis or mistakenly stated the white precipitate was soluble in one or both reagents.

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Paper 9701/35
Advanced Practical Skills 1

Key messages

- Candidates should be reminded to read the information given in each question so that they record suitable results and apposite answers.
- Candidates should ensure their data reflects the precision of the apparatus used.
- Candidates should be given opportunities to discuss errors inherent in a procedure and possible improvements or modifications that could be employed.
- Candidates and supervisors must enter the information regarding session and laboratory on the front cover of the paper so that candidates' results can be matched with those of the relevant supervisor.
- Centres should be aware that the identities of chemicals given in the question paper may differ from those given in the confidential instructions. This is not an error and a statement to this effect is written in the confidential instructions.

General comments

Many candidates were competent in using the techniques involved in the two quantitative exercises. Most also attempted the calculations that followed the collection of the relevant data in **Questions 1** and **2**. Many dealt well with the straightforward data questions. Far fewer responded positively to the latter parts of **Question 2**. **Question 3** responses varied widely: some candidates made accurate, succinct observations and selected suitable reagents for further tests whereas others struggled.

A large majority of candidates completed the paper.

Comments on specific questions

Question 1

In a question involving a number of experimental readings, candidates should note the instruction in the introduction to 'prepare a table in the space provided'. This is usually the best way to record these readings. In such a table, headings must be unambiguous, units must be correct and consideration of the use of a suitable number of decimal places / significant figures must be made.

In exercises involving measuring masses, it is assumed that candidates have access to 2 decimal place balances.

- (a) Most candidates recorded results in a suitable table with only a small number of errors. The most common of these was the use of 'weight' rather than 'mass', the omission of the mass of carbon dioxide or incorrect subtractions.
- (b)(i)(ii) Most candidates correctly calculated the number of moles and masses required.
- (iii) A significant number did not recognise that this calculation involved subtracting the mass of copper(II) carbonate in the mixture from the mass of solid used.

- (iv) A significant number of candidates calculated the number of moles of copper(II) hydroxide but few recognised the need to calculate the ratio or reversed the values.
- (c) This part was answered well only by the better performing candidates. Most candidates correctly calculated the number of moles of hydrochloric acid but few realised that it was necessary to compare this with twice the total number of moles of hydroxide + carbonate.

Question 2

The majority of candidates appeared well prepared in the basic technique of titration. Others need more practice in carrying out the exercise as well as recording and analysing data.

Candidates should be advised to attempt questions even if the data or expressions appear challenging. If unusual expressions are needed, the necessary information will be provided on the question.

- (a) Many candidates demonstrated the ability to obtain concordant results and present them as required. A common omission was the recording of the burette readings for the rough titre. These need not be shown to the same level of accuracy as those for the accurate titres but some numbers should be shown. A number of candidates carried out extra titrations when they already had suitable results.
- (b) The majority of candidates were able to select titres with a total spread of 0.20 cm^3 and give the answer correct to 2 decimal places.
- (c) (i) Most candidates gave answers to the acceptable 3 or 4 significant figures.
(ii) Most successfully calculated the amount of thiosulfate ions present in the mean titre.
(iii)(iv) Many correctly calculated the amount and mass of copper(II) ions present in the solution.
(v)-(vii) The need to include x in the expression caused many candidates to omit all or nearly all of the rest of the question. Although the expressions appeared complex, the actual chemistry was straightforward, and the expression needed in the final calculation was given. The majority of candidates who made an attempt gave creditworthy answers even if these were not completely evaluated.

Question 3

Some candidates followed the introductory instructions and performed well but others used inappropriate words to describe their observations and / or chose incorrect reagents when suggesting tests for unknown ions. Reading through the tests to be carried out before starting any practical work would focus the candidates' minds on the type of reactions that are feasible and what they might observe.

- (a) Most candidates observed the colour change of the solid. A few noticed the condensation forming further up the test-tube but hardly anyone reported testing for the evolution of carbon dioxide.
- (b) (i) Precision in description of colour changes is important. For example, in the test with EDTA the colour becomes a darker blue. 'Goes blue' is insufficient as the solution is blue at the start of the test.
- The change to yellow with hydrochloric acid was reported by many candidates but few saw the fading of blue or the formation of the solid in the test with magnesium.
- (ii) This was not well answered. Few candidates recognised what was happening in **Test 3** and even fewer gave correct charges and state symbols.

- (c) (i) Many candidates used aqueous ammonia and / or aqueous sodium hydroxide but it was not always clear how the test was being carried out. It is necessary to add the reagents to an aqueous solution of a salt of an unknown and to note an observation with the addition of a few drops as well as in excess.
- (ii) Some candidates were able to use their observations from (i) to identify **M** correctly.
- (d) Most candidates drew a suitable table but errors included giving an incomplete / incorrect name / formula of the reagents and omission of the conclusions made from each test. The introduction of the Qualitative analysis section contains the instruction that the name or correct formula of all reagents must be given. The question in this case clearly says that the table must include conclusions.

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Paper 9701/41
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- More care is needed on correct use of vocabulary and chemical symbols – for example the symbol for manganese, is Mn, not mn, MN, or mN.
- Curly arrows should always start in a precise place and should be pointing towards a precise place.
- Where a question requires a candidate to fill in boxes this should always be done in the way specified in the question.
- Abbreviations should never be used except where they are clearly and internationally agreed. The state symbols (s), (l), (g) and (aq) are agreed abbreviations but, for example, e.q., sol (except within the symbol ΔH_{sol}), h, and HUR are not agreed abbreviations and should not be used.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations should always be balanced for substances and electric charge.

General comments

The paper enabled candidates to demonstrate their knowledge of chemistry and their ability to apply that knowledge. Many excellent scripts were seen with precise and detailed answers that explained the chemistry well.

The word ‘it’ should be avoided as ‘it’ is ambiguous. In candidates’ answers to **Question 1(d)(ii)**, it was often impossible to tell whether ‘it’ referred to BaSO₄, Cs₂SO₄, the Ba²⁺ ion or the Cs⁺ ion.

The majority of candidates were able to work through to the end of the paper, suggesting that they had sufficient time.

Comments on specific questions

Question 1

- (a) In questions relating to energy terms, the descriptions ‘more exothermic’, ‘less exothermic’, ‘more endothermic’ and ‘less endothermic’ are much preferred to ‘increases’ and ‘decreases’.
- (b) This was not well known. Acceptable observations included ‘bubbling’ and ‘effervescence’ as these are things that would be seen. However, ‘gas given off’ or ‘hydrogen given off’ are deductions not observations and were not awarded credit.
- (c) $1.04 \times 10^{-5} \text{ mol dm}^{-3}$ was usually calculated, but it was rarer to see the correct final answer of $2.43 \times 10^{-4} \text{ g per } 100 \text{ cm}^3$.
- (d) (i) The majority of candidates found it very difficult to select appropriate data to complete the given task. Most of those that did select the appropriate data went on to use it correctly.

- (ii) Candidates were expected to refer explicitly to the ions involved. So, for example:
- a statement like ‘BaSO₄ has greater attractions’ was not credited, while ‘the attraction between Ba²⁺ ions and SO₄²⁻ ions is greater than the attraction between Cs⁺ ions and SO₄²⁻ ions’ did gain credit
 - when referring to the magnitude of charges and radii it was essential to link such statements to Ba²⁺ and Cs⁺ ions, rather than to Ba and Cs atoms.
- (e) (i) This was answered well. The concept of using $\Delta G = 0$ was well understood. Some candidates left their answer in Kelvin.
- (ii) This question was an excellent example of how important it is to show working. Many candidates did not get a final answer of -24.9. Some of these gained no credit because it was not clear which of the numbers in their calculation was their ΔS value, or whether they had used a correct form of the Gibbs equation. Others clearly stated that a number they had calculated, e.g. +336, was their value for ΔS . They stated the Gibbs equation, $\Delta G = \Delta H - T\Delta S$. They then calculated +32.9 as their answer and gained two marks.

Question 2

- (a) Many candidates recognised the importance of stable ions with partially filled d subshells.
- (b) This question was generally well answered. Some candidates needed to be more careful in the production of the sketch. The ‘hour-glass’ shape should go to zero at the origin and the ‘belt’ should clearly go around this narrowest portion of the hour glass, not completely in front of it or completely behind it.
- (c) (i) This was generally well answered.
- (ii) Weak responses used the terms ‘catalyst’, ‘reactants’ and ‘products’ in the wrong contexts or gave general statements such as ‘adsorption occurs’, ‘bonds weaken’ and ‘desorb’. Good responses were more specific: ‘adsorption of reactants to catalyst surface’, ‘bonds weaken in reactants’ and ‘products desorb from catalyst surface’.
- (d) Many unbalanced equations were seen. Some mistakes appeared to be careless, for example not using the information in the question and giving the formula of manganese(VII) oxide as MnO₇.
- (e) (i) This was generally well answered. Many candidates correctly described the reaction as precipitation or acid-base. Some candidates incorrectly included spectator ions here and in (e)(ii).
- (ii) This was generally well answered.
- (iii) Many could work out that this is a redox reaction; the formula of the manganese species, MnO₂, was rarely seen.

Question 3

- (a) (i) A tangent was usually drawn. Better responses used a ruler and pencil for the tangent. Some very poor tangents were seen and this resulted in answers outside the wide range that was acceptable.
- (ii) Where the graph was not clearly annotated, careful and precise explanation in words was extremely important. The first half-life is 30 s, but it should not be stated that the second half-life is 60 s. It should be stated that the second half-life is from 30 s to 60 s which is a time period of 30 s. This gives supporting evidence to the statement ‘half-life is constant’, while simply stating ‘the first half-life is 30 s, the second half-life is 60 s’ does not. The symbol $t_{1/2}$ was accepted but ‘half-time’ was not credited.
- (b) This was found to be very difficult. Firstly, the use of $k = 0.693 / t_{1/2}$ was quite rare. Secondly, amongst those who used this, a $t_{1/2}$ value of 213 s was more often seen than 160 s.
- (c) (i) Many candidates showed confusion in the terms ‘cell’, which consists of two electrodes, and ‘half-cell’, which consists of one. The abbreviation SHE was accepted as a recognised abbreviation of Standard Hydrogen Electrode.

(ii) Candidates found this very difficult because it required two components – the function of the salt bridge and an explanation of how it performs that function.

(iii) Few diagrams were seen that were not recognisable as a diagram of an electrochemical cell containing a standard hydrogen electrode. Responses commonly missed were the H⁺ ions in the Cr₂O₇²⁻/Cr³⁺ half-cell and the temperature.

Candidates needed to draw a liquid level in each beaker, ensuring this level touches the salt bridge and the electrode in each beaker.

(iv) Many responses did not show the electrons moving from positive to negative.

(d) (i) This discriminated well.

(ii) This method was not well known. Candidates who correctly attempted to use the equation $\Delta G^\circ = -nFE_{\text{cell}}$ often omitted the minus sign or had difficulty deducing that n is equal to four.

Due to an issue with the equation in this question, careful consideration was given to its treatment in marking in order to ensure that candidates who used n=8 were not disadvantaged. The equation will be corrected in the published question paper.

Question 4

(a) The splitting into three lower and two upper orbitals was well appreciated. The energy of these split orbitals compared with the energy of the degenerate orbitals in the isolated ion was not.

(b) (i) This was generally well answered, clearly and precisely.

(ii) Many accurately drawn correct answers, using correct conventions for the three-dimensional bonds, were seen.

(c) This was generally well answered. Some candidates answered with (Fe(CN)₆)⁴⁻, however this is not an iron(III) complex.

(d) Candidates performed poorly on this question and found it very difficult to answer this question in a clear and unambiguous manner. Two key components of good answers seen were as follows:

- ‘hybridisation’ is something that is used to describe atoms; in this case, the C and N atoms are sp² hybridised
- bonds are caused by the overlap of hybridised orbitals and non-hybridised orbitals; in this case, the C–C and C–N σ bonds are caused by head-on overlap of sp² hybridised orbitals and the π bonds are caused by sideways overlap of unhybridised p orbitals.

(e) Many good clear answers that were easy to interpret were seen here. Errors included an intermediate with two plus charges – one within the hexagon and one on the H outside the hexagon – and the leaving group being shown as HCl without a Cl⁻ ion being shown previously.

Question 5

(a) Many referred accurately to:

- the electronegative C=O group in benzoic acid
- the delocalisation of the lone pair on the oxygen atom of phenol into the benzene ring
- the consequent weakening of the O–H bond or stabilisation of the anion
- the electropositive CH₂ group in phenylmethanol
- the consequent strengthening of the O–H bond or destabilisation of the anion.

Some candidates did not specify which compound they were referring to, or when referring to benzoic acid they mentioned ‘the oxygen atom’ without specifying which of the two oxygen atoms they meant. The electropositive group in phenylmethanol could be described as an alkyl group, or as a CH₂ group, but should not be described as a methyl group. The effects of the various inductive effects are better described as strengthening or weakening the O–H bonds, rather than making

these bonds harder or easier to break. The expression ‘OH group’ should not be used when it is the strength of the O–H **bond** that is being discussed.

- (b) A significant number of candidates ignored the instruction to ‘Place a cross (x) in the box if no reaction occurs.’ Credit for blank boxes could not be awarded.
- (c) (i) This question discriminated well.
- (ii) Many candidates could see the significance of the SO₂ and HCl being gaseous. Some incorrectly referenced aqueous conditions. The synthesis of benzoyl chloride would not work with water present.
- (d) (i) This question set a difficult and very precise task to the candidates. Most candidates were able to make a start on the mechanism and some were able to reproduce all of it to a high standard. The task required very careful drawing of the curly arrows involved. Single headed arrows, which show the movement of single electrons, are inappropriate for the description of this mechanism and did not gain credit.
- (ii) The name of the mechanism was not well known.
- (e) (i) This was found difficult. Many candidates drew molecules with only one reactive group. These molecules would not be able to act as monomers. Many candidates drew sections of the polymer chain, rather than discrete monomer molecules.
- (ii) This discriminated well.

Question 6

- (a) This was generally well answered. Some candidates did not state that the two enantiomers are present in a racemic mixture in equal concentrations.
- (b) This discriminated well.
- (c) (i) Good responses stated that the isoelectric point is a pH value.
- (ii) Correct diagrams were rarely seen. The commonest error was the protonation of the amide group, giving –CONH₃⁺. Candidates should know that amides are neutral.
- (d) Correct answers were rare here. The amide group in the R-group of arginine caused great problems to many candidates who formed their peptide bond to this R-group, instead of correctly using the amino group. Many answers with correct peptide linkages incorrectly included more than two repeat units.
- (e) Good answers were rare. Good responses considered both charge and M_r value. Many candidates only considered the M_r value, stating that the dipeptide has the greatest M_r of the three. Some excellent answers appreciating the lack of charge on the arginine, the positive charge on the lysine side-chains and the greater M_r of the dipeptide were seen.
- (f) (i) This discriminated well. Some incorrectly described paper chromatography not TLC.
- (ii) Many good answers were seen here. The best answers referred correctly to R_f values.
- (g) Correct manipulation of the data was found to be very difficult. This required firstly the calculation of the concentration of L in g dm⁻³ and secondly the conversion of this concentration into mol dm⁻³.

Question 7

- (a) (i) Candidates found this a difficult compound to identify all the functional groups. The incorrect group ‘amide’ was often given in candidates’ answers.
- (ii) Many answers did not add up to 13.

- (b) It appeared that many candidates did not remember to include the aromatic protons that are found in two different environments.
- (c) A very precise answer – identifying the nitrogen atom, its lone pair, and the accepting of a proton – was required.
- (d) (i) This was usually answered well. A common incorrect answer was benzoic acid.
- (ii) The correct use of alkaline KMnO_4 to oxidise an aromatic side chain was often seen.
- (e) Some candidates gave their answer for step 5 on the step 4 line, and their answer to step 4 on the step 5 line. Responses for step 4 that included NaOH or any aqueous substances were not credited as these would hydrolyse the acid chloride. The reagents for step 5 are Sn and conc. HCl ; Sn is not a catalyst in this reaction and should not be described as such.
- (f) (i) Some candidates did not refer to concentrations or referred to ‘two solutions’ rather than ‘one solute in two immiscible solvents’. More candidates stated that ‘ K_{pc} is an equilibrium constant’.
- (ii) Most good answers started with an expression such as $1.77 = (x/50)/(0.5 - x/75)$. A common incorrect expression was $1.77 = (x/50)/(0.5/75)$.

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Paper 9701/42
A Level Structured Questions

Key messages

- Candidates need to ensure that corrected work is clear to read. Work that is crossed out should be very clearly crossed out and never overwritten with the new answer.
- Chemical equations, ionic equations and half-equations should always be balanced for substances and charge.
- In organic reaction mechanisms, the starting and finishing points of curly arrows is a key part in the description of the mechanisms.

General comments

This paper gave candidates of all abilities the opportunity to demonstrate their knowledge and understanding of a wide range of chemistry topics. Candidates who had prepared well for the examination were able to attempt all the questions. Many candidates were able to work through to the end of the paper.

Comments on specific questions

Question 1

- (a) The trend and its explanation were well understood by candidates. It was common to see a statement regarding increasing solubility due to ΔH_{latt} and ΔH_{hyd} becoming less exothermic and ΔH_{sol} becoming more exothermic down Group 2. ΔH_{latt} being the dominant factor was less frequently seen.
- (b) (i) This was generally answered well. Most candidates were able to write an expression.
- (ii) This question discriminated well. The commonest error was not converting their solubility from g dm^{-3} to mol dm^{-3} (answer = 5.53×10^{-17}).
- (c) (i) This definition was well known.
- (ii) This was answered well by many candidates. The errors most commonly seen were:
- square planar diagram being drawn
 - diagrams in which three-dimensional bonds were drawn but where the complex could not be tetrahedral.
- (d) (i) This definition was less well known. Many gave a definition of a transition element. The expected answers included:
 - the vacant d orbitals can form dative bonds
 - the vacant d orbitals are energetically accessible.
- (ii) This was generally well answered. Most candidates were able to correctly state the coordination number for these complex ions. The shape and polarity were less well known.
- (e) (i) This proved difficult for many candidates. Most candidates did not identify K_{stab} as an equilibrium constant.

- (ii) Candidates often gave the correct answer here. Common errors included inclusion of $(\text{H}_2\text{O})^6$ or having the charge of the complex ion outside their outer brackets in their expression.
- (iii) Many candidates did not answer both parts of the question. Some identified one equilibrium as being to the right, the other to the left.

Question 2

- (a) This proved difficult for many candidates. Some confused this definition with the explanation of why transition elements can form complex ions.
- (b) This answer was usually correct. A common error was drawing the lobes along two different axes.
- (c) Candidates performed well on this question. The splitting of d orbitals; the absorption of photons of visible light; the excitation of electrons and the observed colour being complementary to the colour absorbed were all described clearly.
- (d) (i) This answer was usually correct.
(ii) This was generally well answered. A common error was the omission of ‘concentration’ or just stating due to the common ion effect.
- (e) Most candidates answered this question well. Some had difficulty with drawing three-dimensional diagrams of the two isomers or drew two identical diagrams. Other errors included use of O_2H for H_2O and N_3H for NH_3 in their diagrams.

Question 3

- (a) (i) This was generally answered well. Some definitions lacked precision and some candidates confused this definition with ionisation energy.
(ii) This explanation was well known and clearly described by many candidates.
(iii) This question discriminated well. Some candidates did not clearly explain that there was less attraction between the nucleus and the incoming electron.
- (b) Many candidates found this question challenging. It was necessary for candidates to understand and select relevant data for this energy cycle calculation. Many correct answers were seen. Common errors included –586 (no division by 2); –262 (no use of 62) or an error in one of their signs, for example +293 or –85 (use of +208).
- (c) Most candidates correctly identified that ΔH_{att} of CdI_2 was less exothermic, however, they often omitted adequate reasoning in terms of Cd^{2+} being larger and attracting I^- ions less strongly.

Question 4

- (a) (i) Most candidates could do this successfully.
(ii) This proved difficult for some candidates. Most were able to calculate the gradient of their graph ($-\Delta S$). However, many candidates were not able to correctly evaluate it to determine ΔS in $\text{J K}^{-1} \text{mol}^{-1}$. Common errors included the omission of multiplying their gradient by 1000 and converting to a positive value.
- (b) (i) Many candidates found it difficult to construct this ionic equation. Some incorrectly gave a general equation $(2\text{MHC}\text{O}_3 \rightarrow \text{M}_2\text{C}\text{O}_3 + \text{CO}_2 + \text{H}_2\text{O})$.
(ii) This was generally well answered.
- (c) (i) Most candidates knew the definition in the syllabus. Some did not give a precise definition, stating the pH would remain unchanged or stay constant.

- (ii) This was generally well answered. A common error was writing a reaction with water, for example:
 $\text{H}_2\text{CO}_3 + \text{H}_2\text{O} \rightarrow \text{HCO}_3^- + \text{H}_3\text{O}^+$.
- (iii) Candidates often gave the correct answer here. A common error was 5.20 from an incorrect Henderson–Hasselbalch equation: $\text{pH} = \text{pK}_a - \log [\text{A}^-] / [\text{HA}]$.

Question 5

- (a) Candidates generally answered this question well. Some common errors were:
- $\text{PbBr}_2(\text{l})$: H_2 at the cathode
 - concentrated $\text{NaCl}(\text{aq})$: O_2 at the anode and Na at the cathode
 - $\text{Cu}(\text{NO}_3)_2(\text{aq})$: NO_2 at the anode and H_2 at the cathode.
- (b) (i) Most candidates gave the correct answer.
- (ii) Most candidates were able to calculate the number of moles of copper ($= 5.51 \times 10^{-3} \text{ mol}$) and the amount of electricity passed ($= 1080 \text{ C}$). Some managed to use these values and $e (1.60 \times 10^{-19})$ to calculate the number of copper ions per mole, L . However, some used the value given on the question paper (in the important values, constants and standards) for $F (96500 \text{ C mol}^{-1})$ instead of completing their own calculation to deduce L .

Question 6

- (a) (i) Those who had learned the electrophilic substitution mechanism found this to be accessible.
- Errors included:
- careless drawing of the curly arrow from the benzene ring to the N of the NO_2^+ , which should start inside the ring system
 - an incorrect structure of the intermediate – the partly delocalised ring should not include the sp^3 carbon
 - the curly arrow in the intermediate starting on the H not on the C–H bond
 - no H^+ ion was shown at the end of the mechanism.
- (ii) Candidates performed well on this question.
- (b) The directing nature of $-\text{COOH}$ and $-\text{OH}$ was well known. A minority replaced the original group with NO_2 ending up with nitrobenzene.
- (c) This was found to be challenging. Most candidates were able to give the correct order for the relative ease of nitration. However, many did not give an adequate explanation and often tried to answer in terms of donating protons or weakening O–H bonds. A common error was referring to ‘electron density’ as charge density.
- (d) (i) Many diagrams were well drawn. The most common error was the positive charge on the terminal nitrogen for the diazonium salt $\text{R}-\text{N}\equiv\text{N}^+$.
- (ii) Candidates performed well on this question. Common errors included the omission of heat and concentrated with Sn / hydrochloric acid in step 1 and the use of NaNO_3 for NaNO_2 in step 2.

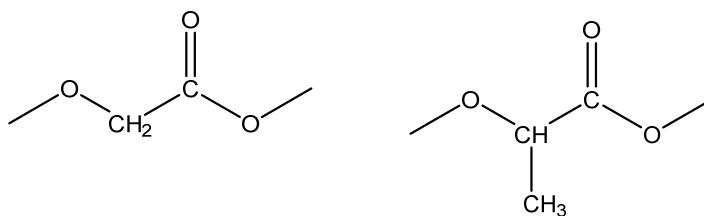
Question 7

- (a) Most candidates stated TMS is used as a standard. The description of the use for D_2O was often imprecise.
- (b) (i) Many candidates found this question challenging. Candidates were more likely to correctly identify the number of peaks observed in the carbon-13 spectra than the proton NMR spectra.
- (ii) Many gave the correct first compound; fewer named pentan-2-one.
- (c) (i) This was generally well answered. Common errors were stating three or four carbons.
- (ii) This proved difficult for many candidates. Most gave the incorrect number of hydrogen atoms.

- (iii) Most candidates found this question difficult. Many did not mention that an optically active molecule would rotate the plane of polarised light.

Question 8

- (a) This was well understood and most candidates could link acidity to weakening the O–H bond. The importance of electron donating groups, such as C₂H₅ in ethanol, and electron withdrawing groups, such as the Cl and C=O group in the two acids, to the strength of the O–H bond was not appreciated by all candidates. Reference to ‘the electronegative oxygen atom’ was not credited as all four compounds contain at least one oxygen atom.
- (b) Candidates performed well on this question. The equation proved the most challenging part, with some using [H] even though categorising it as an oxidation.
- (c) Most candidates were able to do this correctly. Some omitted hydrogen atoms on both hydroxyl groups just showing a fragment.



Ethanoic and propanoic acids also featured as incorrect responses.

- (d) This question discriminated well. Many good answers were seen. Common errors were inclusion of a trivalent carbon or an incorrect peptide linkage such as –COO–NH–.
- (e) Most candidates stated correctly that condensation polymers can be hydrolysed.

Question 9

- (a) Many candidates found this challenging and the question discriminated well. Answers were often not sufficiently detailed. For each substance a clear statement linked to the ability of the lone pair of electrons on the N to accept a proton was required. Most candidates recognised that the alkyl (cyclohexyl) group is an electron donating group and the lone pair on the N of NH₂ is delocalised into the benzene ring. The most common error was omitting the ‘lone pair’ in their explanation.
- (b) (i) This was not well known. Incorrect responses included electrophilic substitution and nucleophilic substitution.
- (ii) Many candidates found this question challenging. Common errors included:
- omitting the lone pair on the N on the amine
 - directing the curly arrow from the N lone pair to an incorrect atom
 - omitting the dipole for the C=O bond
 - omitting a curly arrow on the C=O bond
 - an incorrect intermediate structure
 - the first curly arrow in the intermediate going to the C atom not the C–O bond
 - the second curly arrow in the intermediate starting at the C not on the C–Cl bond to the Cl.
- (iii) This was generally well answered. Some candidates incorrectly suggested the CH₃CO– group would substitute for an H atom in the cyclohexyl ring.

CHEMISTRY

Paper 9701/43
A Level Structured Questions

Key messages

- Candidates must ensure their handwriting is legible. Handwriting that is too small often becomes illegible.
- More care is needed on correct use of vocabulary and chemical symbols – for example the symbol for manganese, is Mn, not mn, MN, or mN.
- Curly arrows should always start in a precise place and should be pointing towards a precise place.
- Where a question requires a candidate to fill in boxes this should always be done in the way specified in the question.
- Abbreviations should never be used except where they are clearly and internationally agreed. The state symbols (s), (l), (g) and (aq) are agreed abbreviations but, for example, e.q., sol (except within the symbol ΔH_{sol}), h, and HUR are not agreed abbreviations and should not be used.
- Candidates should never attempt to write over the top of a previous answer if they wish to change their answer. The original answer should be clearly crossed through, and a new answer should be written in available space.
- Chemical equations should always be balanced for substances and electric charge.

General comments

The paper enabled candidates to demonstrate their knowledge of chemistry and their ability to apply that knowledge. Many excellent scripts were seen with precise and detailed answers that explained the chemistry well.

The word ‘it’ should be avoided as ‘it’ is ambiguous. In candidates’ answers to **Question 1(d)(ii)**, it was often impossible to tell whether ‘it’ referred to BaSO₄, Cs₂SO₄, the Ba²⁺ ion or the Cs⁺ ion.

The majority of candidates were able to work through to the end of the paper, suggesting that they had sufficient time.

Comments on specific questions

Question 1

- (a) In questions relating to energy terms, the descriptions ‘more exothermic’, ‘less exothermic’, ‘more endothermic’ and ‘less endothermic’ are much preferred to ‘increases’ and ‘decreases’.
- (b) This was not well known. Acceptable observations included ‘bubbling’ and ‘effervescence’ as these are things that would be seen. However, ‘gas given off’ or ‘hydrogen given off’ are deductions not observations and were not awarded credit.
- (c) $1.04 \times 10^{-5} \text{ mol dm}^{-3}$ was usually calculated, but it was rarer to see the correct final answer of $2.43 \times 10^{-4} \text{ g per } 100 \text{ cm}^3$.
- (d) (i) The majority of candidates found it very difficult to select appropriate data to complete the given task. Most of those that did select the appropriate data went on to use it correctly.

- (ii) Candidates were expected to refer explicitly to the ions involved. So, for example:
- a statement like ‘BaSO₄ has greater attractions’ was not credited, while ‘the attraction between Ba²⁺ ions and SO₄²⁻ ions is greater than the attraction between Cs⁺ ions and SO₄²⁻ ions’ did gain credit
 - when referring to the magnitude of charges and radii it was essential to link such statements to Ba²⁺ and Cs⁺ ions, rather than to Ba and Cs atoms.
- (e) (i) This was answered well. The concept of using $\Delta G = 0$ was well understood. Some candidates left their answer in Kelvin.
- (ii) This question was an excellent example of how important it is to show working. Many candidates did not get a final answer of -24.9. Some of these gained no credit because it was not clear which of the numbers in their calculation was their ΔS value, or whether they had used a correct form of the Gibbs equation. Others clearly stated that a number they had calculated, e.g. +336, was their value for ΔS . They stated the Gibbs equation, $\Delta G = \Delta H - T\Delta S$. They then calculated +32.9 as their answer and gained two marks.

Question 2

- (a) Many candidates recognised the importance of stable ions with partially filled d subshells.
- (b) This question was generally well answered. Some candidates needed to be more careful in the production of the sketch. The ‘hour-glass’ shape should go to zero at the origin and the ‘belt’ should clearly go around this narrowest portion of the hour glass, not completely in front of it or completely behind it.
- (c) (i) This was generally well answered.
- (ii) Weak responses used the terms ‘catalyst’, ‘reactants’ and ‘products’ in the wrong contexts or gave general statements such as ‘adsorption occurs’, ‘bonds weaken’ and ‘desorb’. Good responses were more specific: ‘adsorption of reactants to catalyst surface’, ‘bonds weaken in reactants’ and ‘products desorb from catalyst surface’.
- (d) Many unbalanced equations were seen. Some mistakes appeared to be careless, for example not using the information in the question and giving the formula of manganese(VII) oxide as MnO₇.
- (e) (i) This was generally well answered. Many candidates correctly described the reaction as precipitation or acid-base. Some candidates incorrectly included spectator ions here and in (e)(ii).
- (ii) This was generally well answered.
- (iii) Many could work out that this is a redox reaction; the formula of the manganese species, MnO₂, was rarely seen.

Question 3

- (a) (i) A tangent was usually drawn. Better responses used a ruler and pencil for the tangent. Some very poor tangents were seen and this resulted in answers outside the wide range that was acceptable.
- (ii) Where the graph was not clearly annotated, careful and precise explanation in words was extremely important. The first half-life is 30 s, but it should not be stated that the second half-life is 60 s. It should be stated that the second half-life is from 30 s to 60 s which is a time period of 30 s. This gives supporting evidence to the statement ‘half-life is constant’, while simply stating ‘the first half-life is 30 s, the second half-life is 60 s’ does not. The symbol $t_{1/2}$ was accepted but ‘half-time’ was not credited.
- (b) This was found to be very difficult. Firstly, the use of $k = 0.693 / t_{1/2}$ was quite rare. Secondly, amongst those who used this, a $t_{1/2}$ value of 213 s was more often seen than 160 s.
- (c) (i) Many candidates showed confusion in the terms ‘cell’, which consists of two electrodes, and ‘half-cell’, which consists of one. The abbreviation SHE was accepted as a recognised abbreviation of Standard Hydrogen Electrode.

(ii) Candidates found this very difficult because it required two components – the function of the salt bridge and an explanation of how it performs that function.

(iii) Few diagrams were seen that were not recognisable as a diagram of an electrochemical cell containing a standard hydrogen electrode. Responses commonly missed were the H⁺ ions in the Cr₂O₇²⁻/Cr³⁺ half-cell and the temperature.

Candidates needed to draw a liquid level in each beaker, ensuring this level touches the salt bridge and the electrode in each beaker.

(iv) Many responses did not show the electrons moving from positive to negative.

(d) (i) This discriminated well.

(ii) This method was not well known. Candidates who correctly attempted to use the equation $\Delta G^\circ = -nFE_{\text{cell}}$ often omitted the minus sign or had difficulty deducing that n is equal to four.

Due to an issue with the equation in this question, careful consideration was given to its treatment in marking in order to ensure that candidates who used n=8 were not disadvantaged. The equation will be corrected in the published question paper.

Question 4

(a) The splitting into three lower and two upper orbitals was well appreciated. The energy of these split orbitals compared with the energy of the degenerate orbitals in the isolated ion was not.

(b) (i) This was generally well answered, clearly and precisely.

(ii) Many accurately drawn correct answers, using correct conventions for the three-dimensional bonds, were seen.

(c) This was generally well answered. Some candidates answered with (Fe(CN)₆)⁴⁻, however this is not an iron(III) complex.

(d) Candidates performed poorly on this question and found it very difficult to answer this question in a clear and unambiguous manner. Two key components of good answers seen were as follows:

- ‘hybridisation’ is something that is used to describe atoms; in this case, the C and N atoms are sp² hybridised
- bonds are caused by the overlap of hybridised orbitals and non-hybridised orbitals; in this case, the C–C and C–N σ bonds are caused by head-on overlap of sp² hybridised orbitals and the π bonds are caused by sideways overlap of unhybridised p orbitals.

(e) Many good clear answers that were easy to interpret were seen here. Errors included an intermediate with two plus charges – one within the hexagon and one on the H outside the hexagon – and the leaving group being shown as HCl without a Cl⁻ ion being shown previously.

Question 5

(a) Many referred accurately to:

- the electronegative C=O group in benzoic acid
- the delocalisation of the lone pair on the oxygen atom of phenol into the benzene ring
- the consequent weakening of the O–H bond or stabilisation of the anion
- the electropositive CH₂ group in phenylmethanol
- the consequent strengthening of the O–H bond or destabilisation of the anion.

Some candidates did not specify which compound they were referring to, or when referring to benzoic acid they mentioned ‘the oxygen atom’ without specifying which of the two oxygen atoms they meant. The electropositive group in phenylmethanol could be described as an alkyl group, or as a CH₂ group, but should not be described as a methyl group. The effects of the various inductive effects are better described as strengthening or weakening the O–H bonds, rather than making

these bonds harder or easier to break. The expression ‘OH group’ should not be used when it is the strength of the O–H **bond** that is being discussed.

- (b) A significant number of candidates ignored the instruction to ‘Place a cross (x) in the box if no reaction occurs.’ Credit for blank boxes could not be awarded.
- (c) (i) This question discriminated well.
- (ii) Many candidates could see the significance of the SO₂ and HCl being gaseous. Some incorrectly referenced aqueous conditions. The synthesis of benzoyl chloride would not work with water present.
- (d) (i) This question set a difficult and very precise task to the candidates. Most candidates were able to make a start on the mechanism and some were able to reproduce all of it to a high standard. The task required very careful drawing of the curly arrows involved. Single headed arrows, which show the movement of single electrons, are inappropriate for the description of this mechanism and did not gain credit.
- (ii) The name of the mechanism was not well known.
- (e) (i) This was found difficult. Many candidates drew molecules with only one reactive group. These molecules would not be able to act as monomers. Many candidates drew sections of the polymer chain, rather than discrete monomer molecules.
- (ii) This discriminated well.

Question 6

- (a) This was generally well answered. Some candidates did not state that the two enantiomers are present in a racemic mixture in equal concentrations.
- (b) This discriminated well.
- (c) (i) Good responses stated that the isoelectric point is a pH value.
- (ii) Correct diagrams were rarely seen. The commonest error was the protonation of the amide group, giving –CONH₃⁺. Candidates should know that amides are neutral.
- (d) Correct answers were rare here. The amide group in the R-group of arginine caused great problems to many candidates who formed their peptide bond to this R-group, instead of correctly using the amino group. Many answers with correct peptide linkages incorrectly included more than two repeat units.
- (e) Good answers were rare. Good responses considered both charge and M_r value. Many candidates only considered the M_r value, stating that the dipeptide has the greatest M_r of the three. Some excellent answers appreciating the lack of charge on the arginine, the positive charge on the lysine side-chains and the greater M_r of the dipeptide were seen.
- (f) (i) This discriminated well. Some incorrectly described paper chromatography not TLC.
- (ii) Many good answers were seen here. The best answers referred correctly to R_f values.
- (g) Correct manipulation of the data was found to be very difficult. This required firstly the calculation of the concentration of L in g dm⁻³ and secondly the conversion of this concentration into mol dm⁻³.

Question 7

- (a) (i) Candidates found this a difficult compound to identify all the functional groups. The incorrect group ‘amide’ was often given in candidates’ answers.
- (ii) Many answers did not add up to 13.

- (b) It appeared that many candidates did not remember to include the aromatic protons that are found in two different environments.
- (c) A very precise answer – identifying the nitrogen atom, its lone pair, and the accepting of a proton – was required.
- (d) (i) This was usually answered well. A common incorrect answer was benzoic acid.
- (ii) The correct use of alkaline KMnO_4 to oxidise an aromatic side chain was often seen.
- (e) Some candidates gave their answer for step 5 on the step 4 line, and their answer to step 4 on the step 5 line. Responses for step 4 that included NaOH or any aqueous substances were not credited as these would hydrolyse the acid chloride. The reagents for step 5 are Sn and conc. HCl ; Sn is not a catalyst in this reaction and should not be described as such.
- (f) (i) Some candidates did not refer to concentrations or referred to ‘two solutions’ rather than ‘one solute in two immiscible solvents’. More candidates stated that ‘ K_{pc} is an equilibrium constant’.
- (ii) Most good answers started with an expression such as $1.77 = (x/50)/(0.5 - x/75)$. A common incorrect expression was $1.77 = (x/50)/(0.5/75)$.

CHEMISTRY

Paper 9701/51
Planning, Analysis and Evaluation

Key messages

- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures. One significant figure will usually be insufficient at A level.
- Candidates need to be aware that volumetric apparatus (burettes, pipettes, volumetric flasks) should be used to maintain the degree of accuracy required when making up standard solutions.
- Candidates should be aware that if the value measured requires an initial and final reading, e.g. titres using a burette, temperature change using a thermometer and mass of a sample using a balance then the half a graduation is multiplied by two before dividing by the value measured. However, if only one reading is required, e.g. volume of a solution using a measuring cylinder or using a pipette, then the half graduation is not multiplied by two.

General comments

A wide range of performance was observed from candidates. There were some excellent, well-constructed answers to the descriptive elements of the paper and better performing candidates produced clear and concise responses to calculations with sufficient working. There were also a number of responses that had a high proportion of unanswered questions.

The need for detailed reading of the question and subsequent use of the information contained is important, such as **Questions 1(b)** and **1(c)**.

Many candidates struggled to identify and explain the weaknesses of the experimental procedures used and to suggest realistic improvements. **Questions 1(d)(i), 1(g)** and the explanation part of **Question 2(e)(iv)** were among the most poorly answered on the paper.

The responses given to **Questions 2(b)(i)** and **(ii)** showed a poor appreciation of the appropriate use of volumetric apparatus.

Responses to **Question 1(d)(ii)** highlighted the need for additional practice of percentage error calculations. Although many candidates showed their working clearly, there were still lots of errors.

The responses given to **Question 2(e)(v)** indicate that most candidates would benefit from more practice in the graphical determination of half-lives.

Comments on specific questions

Question 1

- (a) The majority of candidates were able to calculate the mass of NaCl(s) needed to produce the required volume of sodium chloride solution. The most frequent incorrect answer was 11.7 g, where candidates did not divide by 4 as only 250 cm³ of solution was required.

Most candidates gave their answer to 3 or, less frequently, 4 significant figures. Only a few gave the answer to 2 significant figures. Incorrect rounding was very rare.

- (b) This question required candidates to describe the standard laboratory practice used when weighing by difference. A careful reading of the information in the question provided the candidates with a sequence of events to base their response. The best responses began where the student has weighed the mass of NaCl(s) in a weighing boat and then transferred the solid mass to a beaker. To determine the exact mass added to the beaker, the mass of the weighing boat (with any residual NaCl) following transfer must be recorded. Many other unnecessary masses were included in a large number of responses, ignoring the timeline established in the question. Recording the mass of the empty weighting boat and then adding the correct mass of NaCl(s) did not gain credit as this method does not account for any solid left in the weighing boat following transfer to the beaker.

It is important that candidates use appropriate scientific terminology and conventions in their responses. A small number of candidates incorrectly used the term ‘weight’ instead of ‘mass’ in their answer.

- (c) This part of the question also required candidates to describe a standard laboratory procedure; making up a solution of known concentration. The question information gave candidates the starting point for their response; a small beaker containing the mass of NaCl(s) calculated in (a), from which the standard method for making a solution of accurately known concentration was required.

The most common omissions were:

- dissolving the solid in the beaker before transfer
- washing the beaker into the volumetric flask.

It is worth noting that shaking the volumetric flask after it has been filled to the 250cm³ mark is done to ensure a uniform solution, not to dissolve any remaining solid (which should have been fully dissolved before topping up). A few candidates even incorrectly suggested the use of a beaker, measuring cylinder or conical flask to make up the final solution.

- (d) (i) Many candidates found it challenging to evaluate the method described in the question and suggest a valid improvement. Heating the precipitate to constant mass, thus ensuring it is completely dry, is the most effective extra step that could be added to improve this method.

There are a number of other creditworthy extra steps. These include washing the precipitate, rinsing the beaker into the filter and filtering the solution again.

Some candidates suggested mixing the solutions, but this had already been done in step 1 of the method.

- (ii) Candidates would benefit from improving their performance on the calculation of percentage errors. The uncertainty in the measurement of a burette reading is estimated as half of the smallest scale division i.e. $\pm 0.05\text{ cm}^3$. The volume of solution is calculated as the difference between two burette readings. Therefore, the absolute uncertainty in the volume added is $(2 \times \pm 0.05\text{ cm}^3) = \pm 0.10\text{ cm}^3$.

$$\text{So, in this case, the percentage error} = \frac{2 \times 0.05}{10.00} \times 100 = 1\%.$$

It was essential for candidates to include sufficient working to show that the correct steps were used in order to gain credit.

Common errors included the use of ± 0.005 as the error in a burette reading and not multiplying by 2, as the titre volume is the difference between two burette readings.

- (iii) In order to ensure the results are reliable, it was necessary to obtain more data, most commonly by ‘taking more readings’ or ‘repeating the experiment’, and, importantly, using it to check that the results obtained are consistent. This can also be achieved by plotting a graph and checking that data obeys a line of best fit and there are no anomalous points.

The suggestion of many candidates simply to take an average of repeats does not ensure the results are reliable: it only reduces the effect of any ‘unreliable’ or anomalous results.

- (e) (i) This question was well answered with nearly all candidates gaining credit. There were very few curves or poorly drawn lines of best fit.
- (ii) Most candidates were able to read the volume of $\text{NaCl}(\text{aq})$ corresponding to the point of intersection from the graph and to deduce the volume of the aqueous lead compound by subtracting the volume of $\text{NaCl}(\text{aq})$ from 50 cm^3 . There were, however, a significant number who wrongly gave the volume of $\text{NaCl}(\text{aq})$ as 30 cm^3 , presumably taken from the data point with the greatest mass of precipitate. Others chose their volumes without any obvious supporting evidence.

A whole-number molar ratio was produced by a small number of candidates only.

- (f) The formula given had to be consistent with the ratio stated in (e)(ii). A number of candidates gave a formula that was unrelated to their ratio. Prior knowledge of the formula of lead(II) chloride (PbCl_2) led to some giving this as their answer even though their ratio did not support it. A large number of candidates gave formulae for compounds involving sodium.
- (g) Candidates found this question challenging and very few gained full credit. It is important to note that the question asked for a modification, not a whole new experiment. Creditworthy answers needed to include a change that would improve the method suggested by the student.

Investigation 1: The most obvious modification is to increase the time allowed for the precipitate to settle before measurement. A common incorrect answer was to allow a longer time for the reaction to reach completion. The reaction between the two ions in aqueous solution producing a precipitate of insoluble salt lead(II) chloride is fast and so would happen almost instantaneously as the solutions are mixed.

Investigation 2: Very few candidates produced a correct answer to this part. Most incorrect answers involved ensuring that the total volume of the mixed solutions was the same in each case. This suggests that the candidates had not fully understood the aim and method being used here. Using volumes of lead compound from 9 cm^3 to 1 cm^3 changes the whole experiment so that it is identical to investigation 1 and was not deemed creditworthy.

Question 2

- (a) (i) The reaction mixture in the described experiment is maintained at $35\text{ }^\circ\text{C}$ for 45 minutes, then heated to $50\text{ }^\circ\text{C}$ before removing the final sample. A water bath with thermostatic temperature control is the best method to achieve this range of temperatures without the use of a naked flame.
- (ii) Most candidates appreciated that flammable substances are involved in this experiment. Propanone, 2-bromo-2-methylpropane and methylpropan-2-ol are all flammable liquids. There were a very small number who mentioned the non-existent substance 2-bromo-2-methylpropanone.
- (b) In both (i) and (ii), candidates were asked to name a piece of equipment and give its capacity. A volumetric pipette of the correct capacity could be used in each case, but only a small number appeared to appreciate that these are calibrated to contain and dispense a single fixed volume. A graduated pipette of suitable volume will suffice as an alternative but would introduce greater uncertainty.

A significant number of candidates wrongly suggested using transfer, dropping, teat or Pasteur pipettes, which are not graduated or calibrated for any particular volume, or a syringe which has significantly greater uncertainty in measured volume.

In (i), a 1.00 cm^3 pipette is most suitable to deliver exactly the required volume. A burette is also an acceptable choice.

In (ii), a 10.00 cm^3 pipette, which typically has an uncertainty in measurement of $\pm 0.02\text{ cm}^3$, is the best choice to transfer exactly this volume. A burette would not be suitable here as only the sample volume is removed from the reaction mixture.

- (c) A number of candidates did not recognise the reason for cooling the reaction mixture with ice. The idea of reducing the rate of reaction was required for the mark; ‘cooling’ alone or ‘reducing evaporation’ were not creditworthy.

- (d) Identification of the titre value as dependent variable proved to be quite difficult for a large number of candidates. Common incorrect answers included ‘concentration of hydrogen or bromide ions’, ‘time taken for indicator to change colour’ and ‘rate of hydrolysis’.
- (e) (i) Most candidates successfully completed Table 2.1 with values expressed to two decimal places. Some candidates dropped a trailing zero, i.e. 16.1 rather than 16.10 and 46 rather than 46.00.
- (ii) Many candidates performed well here but some omitted ‘concentration’ from their answer.
- (iii) On the whole, candidates were able to plot the points accurately using the axes provided. Many candidates drew a suitable curved line of best fit, others would have benefitted from more practice of this skill.
- (iv) Almost all candidates identified the anomaly correctly (600, 29.50), but explaining how it was caused proved much more difficult. The value of ($V_{\text{final}} - V_t$) is below the line of best fit on the grid, therefore V_t is greater than expected, indicating that the reaction had continued after 600 s, producing more hydrogen ions.
- (v) Candidates seemed to find this part challenging. Many candidates were unable to list coordinates taken from their line of best fit in the form (x,y) and this made it difficult for them to determine two half-lives correctly. Although not specifically required, some used construction lines on the graph to assist in half-life measurement.
- (vi) A high proportion of candidates identified the reaction as first order when the half-life values they obtained in (e)(v) were similar. Credit was given for second and zero order, provided their half-life values supported that conclusion and a suitable explanation was given.

CHEMISTRY

Paper 9701/52
Planning, Analysis and Evaluation

Key messages

- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures. One significant figure will usually be insufficient at A level.
- Candidates need to be aware that volumetric apparatus (burettes, pipettes, volumetric flasks) should be used to maintain the degree of accuracy required when making up standard solutions.
- Candidates should be aware that if the value measured requires an initial and final reading, e.g. titres using a burette, temperature change using a thermometer and mass of a sample using a balance then the half a graduation is multiplied by two before dividing by the value measured. However, if only one reading is required, e.g. volume of a solution using a measuring cylinder or using a pipette, then the half graduation is not multiplied by two.

General comments

In general, candidates seemed well-prepared for this examination.

If a single answer is asked for, two (or three) answers should not be given as incorrect statements may contradict correct answers.

Centres should include as much practical work as possible in their course, so that candidates are familiar with common experimental techniques and apparatus.

Comments on specific questions

Question 1

- (a) This response required candidates to complete a simple diagram showing gas collection by displacement of water. Many candidates produced excellent diagrams. However, a significant number drew delivery tubing going through the sides of water troughs and measuring cylinders. A significant number of candidates introduced gas syringes which were not available.
- (b) (i) This question involved one of the finer points of technique when using magnesium ribbon; that of removing the oxide layer. A number of candidates recognised the need for sandpaper. Incorrect responses concentrated on washing or an incorrect attempt at chemical methods of removal, often with a less reactive metal.
- (ii) Most candidates knew that they needed to know the mass of magnesium.
- (c) (i) This was well answered and a variety of acceptable approaches were seen. Only a few candidates did not apply the 1 : 2 stoichiometric ratio. One common error was to assume the A_r of Mg was 24, rather than 24.3 which introduced an error of over 1% when determining the moles of Mg used.
- (ii) Many candidates realised that a measuring cylinder could be used because the HCl was in excess. Candidates who performed less well tried to justify the use of a measuring cylinder due to a lack of need for accuracy / precision.

- (d) This question was considered ambiguous and therefore full marks were awarded to all candidates for this question to ensure that no candidates were disadvantaged. The question paper has been amended for publication after the exam series.
- (e) (i) Candidates would benefit from further practice of percentage error calculations. Using a measuring cylinder requires only one reading, hence the correct answer was 0.685%; 1.37% was a very common answer.
- (ii) This was a challenging calculation and only a minority of candidates were successful. Many candidates obtained a calculated value of the molar volume of a gas at room temperature and pressure of around 150 cm^3 whereas the expected value is 24000 cm^3 .

A common error was to use the number of moles of HCl and not the number of moles of Mg in the calculation.

- (f) This was a challenging question. Candidates needed to give a reason for the volume of gas collected being too low. A variety of correct and incorrect methods were seen.

It was expected that candidates would focus upon gas loss before the stopper was inserted and a number of candidates appreciated the need to keep the reactants separate before the bung was inserted. Other candidates focused upon the solubility of hydrogen and, although not significant, this was allowed as a viable reason for a lower than expected volume of gas collection.

A common, unaccepted answer was a general leakage of gas from the system.

Question 2

- (a) Nearly all candidates knew the independent variable was temperature.
- (b) There were many variables that needed to be controlled and candidates only needed to give two of these. Many candidates lost credit by introducing an unnecessary third (or fourth) incorrect controlled variable.
- (c) (i) The three key points of making up a standard solution from a solution were known by most candidates. These points were:
- determining the volume of $0.500\text{ mol dm}^{-3}\text{ H}_2\text{O}_2(\text{aq})$ needed
 - transferring this volume using suitable volumetric apparatus, such as a burette, to a volumetric flask
 - topping the solution up to the 250 cm^3 mark with distilled water.

Nearly all candidates determined the volume of $\text{H}_2\text{O}_2(\text{aq})$ needed.

Some candidates opted to use a burette to transfer 50.0 cm^3 of $0.500\text{ mol dm}^{-3}\text{ H}_2\text{O}_2(\text{aq})$ into a beaker and subsequently transferring from the beaker to the volumetric flask. This was acceptable as long as rinsing of the beaker took place.

Common errors included:

- using a measuring cylinder to transfer 50.0 cm^3 of $0.500\text{ mol dm}^{-3}\text{ H}_2\text{O}_2(\text{aq})$
- omission of rinsing an intermediate beaker, if used
- rinsing of the burette; this would place more than 50.0 cm^3 of $0.500\text{ mol dm}^{-3}\text{ H}_2\text{O}_2(\text{aq})$ into the volumetric flask.

- (ii) Nearly all answered this correctly as they knew *chemically resistant* gloves should be worn.
- (d) (i) Most candidates completed the table without error.

- (ii) Plotting of the points caused very few problems. There was the occasional error, usually plotting the x -coordinate. The line of best fit was usually drawn successfully.

Candidates need to realise that if any coordinates of a point to be plotted are off the grid provided then they should go back and look at the table to check if they have calculated or rounded the points correctly in the previous question. Many had an x -coordinate as -4.19 which was off the x -scale. Checking of rounding would have revealed this coordinate to be -4.20 which was on the x -scale.

- (iii) Virtually all candidates identified their most anomalous point, but the explanation was difficult. Many did not appreciate that each temperature involved continuous readings of gas volume and a stop-watch was not stopped. Candidates who performed less well did not understand the nature of the experiment and believed that the temperature was recorded at various time intervals.
- (iv) This question was well answered. Some chose coordinates which were too close to one another, and some gave the y -coordinate first; most candidates used correctly read values. Some did not give the gradient to three significant figures.
- (v) There were many correct answers. Some candidates made life difficult by putting x and y values into simultaneous equations for the straight line instead of just using the expression for the gradient. A few succeeded with this method but most who tried this approach made errors in their lengthy mathematics.
- (e) This was generally well answered, but many candidates wrote about the experiment not being reliable as no average was taken, indicating they had not understood what was done during the experiment.

CHEMISTRY

Paper 9701/53
Planning, Analysis and Evaluation

Key messages

- Candidates should be aware of the need to use an appropriate number of significant figures in numerical answers even when a question does not specify an exact number of significant figures. One significant figure will usually be insufficient at A level.
- Candidates need to be aware that volumetric apparatus (burettes, pipettes, volumetric flasks) should be used to maintain the degree of accuracy required when making up standard solutions.
- Candidates should be aware that if the value measured requires an initial and final reading, e.g. titres using a burette, temperature change using a thermometer and mass of a sample using a balance then the half a graduation is multiplied by two before dividing by the value measured. However, if only one reading is required, e.g. volume of a solution using a measuring cylinder or using a pipette, then the half graduation is not multiplied by two.

General comments

A wide range of performance was observed from candidates. There were some excellent, well-constructed answers to the descriptive elements of the paper and better performing candidates produced clear and concise responses to calculations with sufficient working. There were also a number of responses that had a high proportion of unanswered questions.

The need for detailed reading of the question and subsequent use of the information contained is important, such as **Questions 1(b)** and **1(c)**.

Many candidates struggled to identify and explain the weaknesses of the experimental procedures used and to suggest realistic improvements. **Questions 1(d)(i), 1(g)** and the explanation part of **Question 2(e)(iv)** were among the most poorly answered on the paper.

The responses given to **Questions 2(b)(i)** and **(ii)** showed a poor appreciation of the appropriate use of volumetric apparatus.

Responses to **Question 1(d)(ii)** highlighted the need for additional practice of percentage error calculations. Although many candidates showed their working clearly, there were still lots of errors.

The responses given to **Question 2(e)(v)** indicate that most candidates would benefit from more practice in the graphical determination of half-lives.

Comments on specific questions

Question 1

- (a) The majority of candidates were able to calculate the mass of NaCl(s) needed to produce the required volume of sodium chloride solution. The most frequent incorrect answer was 11.7 g, where candidates did not divide by 4 as only 250 cm³ of solution was required.

Most candidates gave their answer to 3 or, less frequently, 4 significant figures. Only a few gave the answer to 2 significant figures. Incorrect rounding was very rare.

- (b) This question required candidates to describe the standard laboratory practice used when weighing by difference. A careful reading of the information in the question provided the candidates with a sequence of events to base their response. The best responses began where the student has weighed the mass of NaCl(s) in a weighing boat and then transferred the solid mass to a beaker. To determine the exact mass added to the beaker, the mass of the weighing boat (with any residual NaCl) following transfer must be recorded. Many other unnecessary masses were included in a large number of responses, ignoring the timeline established in the question. Recording the mass of the empty weighting boat and then adding the correct mass of NaCl(s) did not gain credit as this method does not account for any solid left in the weighing boat following transfer to the beaker.

It is important that candidates use appropriate scientific terminology and conventions in their responses. A small number of candidates incorrectly used the term ‘weight’ instead of ‘mass’ in their answer.

- (c) This part of the question also required candidates to describe a standard laboratory procedure; making up a solution of known concentration. The question information gave candidates the starting point for their response; a small beaker containing the mass of NaCl(s) calculated in (a), from which the standard method for making a solution of accurately known concentration was required.

The most common omissions were:

- dissolving the solid in the beaker before transfer
- washing the beaker into the volumetric flask.

It is worth noting that shaking the volumetric flask after it has been filled to the 250cm³ mark is done to ensure a uniform solution, not to dissolve any remaining solid (which should have been fully dissolved before topping up). A few candidates even incorrectly suggested the use of a beaker, measuring cylinder or conical flask to make up the final solution.

- (d) (i) Many candidates found it challenging to evaluate the method described in the question and suggest a valid improvement. Heating the precipitate to constant mass, thus ensuring it is completely dry, is the most effective extra step that could be added to improve this method.

There are a number of other creditworthy extra steps. These include washing the precipitate, rinsing the beaker into the filter and filtering the solution again.

Some candidates suggested mixing the solutions, but this had already been done in step 1 of the method.

- (ii) Candidates would benefit from improving their performance on the calculation of percentage errors. The uncertainty in the measurement of a burette reading is estimated as half of the smallest scale division i.e. $\pm 0.05\text{ cm}^3$. The volume of solution is calculated as the difference between two burette readings. Therefore, the absolute uncertainty in the volume added is $(2 \times \pm 0.05\text{ cm}^3) = \pm 0.10\text{ cm}^3$.

$$\text{So, in this case, the percentage error} = \frac{2 \times 0.05}{10.00} \times 100 = 1\%.$$

It was essential for candidates to include sufficient working to show that the correct steps were used in order to gain credit.

Common errors included the use of ± 0.005 as the error in a burette reading and not multiplying by 2, as the titre volume is the difference between two burette readings.

- (iii) In order to ensure the results are reliable, it was necessary to obtain more data, most commonly by ‘taking more readings’ or ‘repeating the experiment’, and, importantly, using it to check that the results obtained are consistent. This can also be achieved by plotting a graph and checking that data obeys a line of best fit and there are no anomalous points.

The suggestion of many candidates simply to take an average of repeats does not ensure the results are reliable: it only reduces the effect of any ‘unreliable’ or anomalous results.

- (e) (i) This question was well answered with nearly all candidates gaining credit. There were very few curves or poorly drawn lines of best fit.
- (ii) Most candidates were able to read the volume of $\text{NaCl}(\text{aq})$ corresponding to the point of intersection from the graph and to deduce the volume of the aqueous lead compound by subtracting the volume of $\text{NaCl}(\text{aq})$ from 50 cm^3 . There were, however, a significant number who wrongly gave the volume of $\text{NaCl}(\text{aq})$ as 30 cm^3 , presumably taken from the data point with the greatest mass of precipitate. Others chose their volumes without any obvious supporting evidence.

A whole-number molar ratio was produced by a small number of candidates only.

- (f) The formula given had to be consistent with the ratio stated in (e)(ii). A number of candidates gave a formula that was unrelated to their ratio. Prior knowledge of the formula of lead(II) chloride (PbCl_2) led to some giving this as their answer even though their ratio did not support it. A large number of candidates gave formulae for compounds involving sodium.
- (g) Candidates found this question challenging and very few gained full credit. It is important to note that the question asked for a modification, not a whole new experiment. Creditworthy answers needed to include a change that would improve the method suggested by the student.

Investigation 1: The most obvious modification is to increase the time allowed for the precipitate to settle before measurement. A common incorrect answer was to allow a longer time for the reaction to reach completion. The reaction between the two ions in aqueous solution producing a precipitate of insoluble salt lead(II) chloride is fast and so would happen almost instantaneously as the solutions are mixed.

Investigation 2: Very few candidates produced a correct answer to this part. Most incorrect answers involved ensuring that the total volume of the mixed solutions was the same in each case. This suggests that the candidates had not fully understood the aim and method being used here. Using volumes of lead compound from 9 cm^3 to 1 cm^3 changes the whole experiment so that it is identical to investigation 1 and was not deemed creditworthy.

Question 2

- (a) (i) The reaction mixture in the described experiment is maintained at $35\text{ }^\circ\text{C}$ for 45 minutes, then heated to $50\text{ }^\circ\text{C}$ before removing the final sample. A water bath with thermostatic temperature control is the best method to achieve this range of temperatures without the use of a naked flame.
- (ii) Most candidates appreciated that flammable substances are involved in this experiment. Propanone, 2-bromo-2-methylpropane and methylpropan-2-ol are all flammable liquids. There were a very small number who mentioned the non-existent substance 2-bromo-2-methylpropanone.
- (b) In both (i) and (ii), candidates were asked to name a piece of equipment and give its capacity. A volumetric pipette of the correct capacity could be used in each case, but only a small number appeared to appreciate that these are calibrated to contain and dispense a single fixed volume. A graduated pipette of suitable volume will suffice as an alternative but would introduce greater uncertainty.

A significant number of candidates wrongly suggested using transfer, dropping, teat or Pasteur pipettes, which are not graduated or calibrated for any particular volume, or a syringe which has significantly greater uncertainty in measured volume.

In (i), a 1.00 cm^3 pipette is most suitable to deliver exactly the required volume. A burette is also an acceptable choice.

In (ii), a 10.00 cm^3 pipette, which typically has an uncertainty in measurement of $\pm 0.02\text{ cm}^3$, is the best choice to transfer exactly this volume. A burette would not be suitable here as only the sample volume is removed from the reaction mixture.

- (c) A number of candidates did not recognise the reason for cooling the reaction mixture with ice. The idea of reducing the rate of reaction was required for the mark; ‘cooling’ alone or ‘reducing evaporation’ were not creditworthy.

- (d) Identification of the titre value as dependent variable proved to be quite difficult for a large number of candidates. Common incorrect answers included ‘concentration of hydrogen or bromide ions’, ‘time taken for indicator to change colour’ and ‘rate of hydrolysis’.
- (e) (i) Most candidates successfully completed Table 2.1 with values expressed to two decimal places. Some candidates dropped a trailing zero, i.e. 16.1 rather than 16.10 and 46 rather than 46.00.
- (ii) Many candidates performed well here but some omitted ‘concentration’ from their answer.
- (iii) On the whole, candidates were able to plot the points accurately using the axes provided. Many candidates drew a suitable curved line of best fit, others would have benefitted from more practice of this skill.
- (iv) Almost all candidates identified the anomaly correctly (600, 29.50), but explaining how it was caused proved much more difficult. The value of ($V_{\text{final}} - V_t$) is below the line of best fit on the grid, therefore V_t is greater than expected, indicating that the reaction had continued after 600 s, producing more hydrogen ions.
- (v) Candidates seemed to find this part challenging. Many candidates were unable to list coordinates taken from their line of best fit in the form (x,y) and this made it difficult for them to determine two half-lives correctly. Although not specifically required, some used construction lines on the graph to assist in half-life measurement.
- (vi) A high proportion of candidates identified the reaction as first order when the half-life values they obtained in (e)(v) were similar. Credit was given for second and zero order, provided their half-life values supported that conclusion and a suitable explanation was given.